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INCANDESCENT ELECTRIC LAMPS AT THE INTERNATIONAL EXHIBITION OF ELECTRICITY.

By the COUNT DU MONCEL.

Translated from "La Lumiere Electrique."

In a previous article* we indicated in what case this system of Electric Lighting was specially applicable, and we saw that henceforth, thanks to important improvements recently introduced, it could be employed for the interior of houses, where light of feeble intensity is used; we have seen that several castles in England were lighted in this way, and that a certain number of houses in the city of New York had subscribed for the light furnished by the Edison Electric Light Company. Since the successful introduction of these lamps a great number of systems of the same kind have been brought out by different inventors, and without speaking of such well known ones as those of Edison, Swan, Maxim, Lane, Fox, Sawyer, we know of about fifteen inventions, bearing more or less upon the subject. It, therefore, seems to us an opportune moment to enter into circumstantial details about this method of lighting, which, up to this moment, has not excited any great interest in Europe, for various reasons which we have enumerated in different articles published in this journal at the commencement of the year 1880, of which the principal one was the relative considerable expenditure of motive force to produce a light of given intensity. It should be borne in mind that the luminous power of an incandescent body increases in a much greater ratio than the calorific intensity; therefore, by the very fact that incandescent lamps permit a greater division of the electric light, a loss is caused by the weakening of the radiating power resulting from the same. Nevertheless, the satisfactory results recently obtained force us to pass these systems of electric lighting in series, and we will begin naturally enough with that of Mr. Edison, which has made the most noise in the world, and which has attracted attention to this manner of lighting by electricity.

EDISON'S SYSTEM OF ELECTRIC LIGHTING.

The incandescent system was first represented by lamps made from an incandescent platinum wire, and the interesting experiments made in 1879 by M. de Changy, should be recollected; but the practical workings of this system were not satisfactory, principally because of the disaggregation and partial fusion of the wires, and in spite of the numerous improvements brought to bear on this system by Mr. Edison, who, by one of the most ingenious of processes, had rendered them

* "La Lumiere Electrique," Aug. 20, 1881.

more infusible and harder, still they had to be absolutely rejected—at least for ordinary lamps. Then it was suggested to employ carbon which, if not allowed to burn, is infusible in the highest heat developed in the lamps, and different arrangements of apparatus were put together at various times by King, Lodyguine, Bouliguine, Swan, Sawyer, etc., some avoiding combustion by enclosing the lamps in receptacles where a vacuum had been obtained, others by filling these receptacles with gases unfit for combustion, as nytrogen or oxide of carbon, or simply by leaving the air shut up in the receptacle to be vitiated by an incipient combustion.

All these attempts had but partially succeeded, to say nothing more, when, in 1879, the new incandescent carbon lamp of Mr. Edison was announced, and many savants, and myself in particular, doubted the exactness of the allegations which came to us from America. The carbonized paper horse shoe appeared incapable of resisting mechanical shocks, and of supporting incandescence for any length of time. At this epoch Mr. Swan himself said that up to that time he had not been able to obtain any very satisfactory results by an analagous disposition of the incandescent organ.

Mr. Edison, however, was not abashed, and in spite of the lively opposition made to his lamps, in spite of the bitter polemic of which he was the object, he did not cease to perfect it for practical purposes, and has at last produced lamps, which we have seen at the Exposition, and which can be admired by all the world for their perfect steadiness. These lamps, to the number of 160, light the two salons reserved for the discoveries of the ingenious American inventor, and we shall see still more important results upon the installation of the great machine which is expected from America.

As at present made, these lamps are sufficiently solid and can last a long time. The originally fragile carbon has become extremely elastic and hard, and of such attenuation that it can be well compared in size to a horse hair. By a cleverly combined system of fastening the platinum, conducting wires are not exposed to be cut, and they are so sealed in the glass receiver that their change of volume under the action of heat does not endanger the perfection of the vacuum. By the way the carbons are treated when the vacuum is made in the globe, the bubbles of air enclosed in their pores and which, in escaping, disaggregate the surface, are evacuated before closing the lamp, and at the same time the filament of carbon acquires a peculiar density and hardness, as was the case with the platinum wires. To obtain this result the carbonized filament must be brought into incandescense while the vacuum is being made. The very nature of the substance of vegetable origin employed in its fabrication, has been modified.

Fibers of bamboo are now used instead of the paper originally employed. These are carbonized by a certain process, and the successive transformation of these fibers into carbon filaments may be followed in several collections to be seen at

Fig. 1.

Fig. 2.

Mr. Edison's exposition, and which will gratify the curious, and are worthy of study. According to Mr. Batchelor and Mr. O. A. Moses, co-laborers of Mr. Edison, and who represent him at the exposition, the resistance of these filaments is 125 ohm, when brought up to an incandescence corresponding to 16 candles; but it can vary according to the luminous power desired of the lamps, for it can be distributed between two lamps, whose filaments are correspondingly more or less long. Their extremities, which are

enlarged, are pressed in a kind of pincer which terminates the platinum conductors, and which are soldered by an electrolytically deposited copper. Figs. 1, 2, 3 and 4 represents the actual arrangement of these lamps. Their duration, from what I have been assured, is long enough; however, they must wear out. Although most of them may have served for 1,200 hours, the question may be asked whether a lamp capable of deterioration may be considered a practical thing; but if it is considered that this lamp can be furnished for 30 cents, that the adjustment on its support cannot be any simpler than

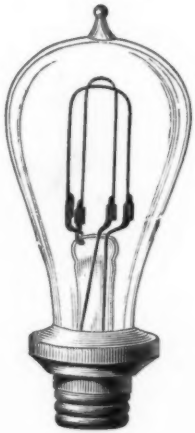


Fig. 3.

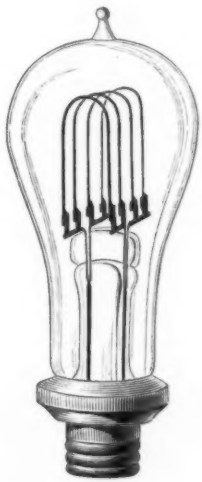


Fig. 4.

it is, which is evident on inspection, it is easily seen there is no more trouble to replace one than to renew a broken lamp shade.

What constitutes Mr. Edison's system is not alone his lamps, it is the totality of the arragements referring to them and which have attained such a degree of simplicity that henceforth nothing remains to be desired in practice. Generating machines, distribution of circuits, installation, indicating and regulating apparatus, meters for measuring the amount of current employed are all combined for immediate application. As we have said, this application is about being made in a part of the city of New York, where a great number of houses are to be lighted by this system, by means of a subterranean distribution from a central station, from which also motive power will be distributed to the houses.

This central station will be provided with twelve steam engines of 150 horse power each, actuating dynamo-electric machines, each of which will be capable to supply, it is said, 2,400 lamps of 8 candle power. The current furnished to these lamps comes through a branch taken before each house from the large-sized conductors laid in the streets. These deviations bring the poles of the generator into each house, where the lamp wires can be brought in connection with them, thus rendering each house independent of any other, both for a supply of light and motive power.

When it is considered that the system of distribution adopted by Mr. Edison, the total resistance of the exterior circuit is extremely reduced and that with 2,400 lamps it is only $\frac{64}{2,400}$, say, about .026 of an ohm, it can be seen that a very feeble resistance should be given to the generating machine; so that its first arrangement has been modified. To begin with: The field magnets were arranged on a derivation taken from the commutator, putting it into the induced circuit as in Wheatstone's and Siemens' system. Then the armature was arranged on Sie-

mens' principle, so that the wire consisted of bars of copper. These bars lie close to each other around the cylinder which forms the armature, and they generate the current. Their extremities correspond to discs of copper (at right angles to them) laid one against the other at the ends of the cylinder, and insulated from each other. Each bar is fastened to its corresponding discs in such a way as to form a single circuit enveloping the cylinder longitudinally, and which is made perfect through the coupled bars two and two with the commutator blocks (made after the Grammes pattern). Figs.

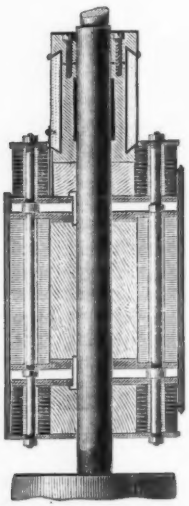


Fig. 5.

5 and 6 give an idea of this new arrangement. The center of the cylinder itself is occupied outside of the rotating axle by a cylinder of wood, which, in its turn, is surrounded by a thick tube made of a series of very thin discs of iron, separated from each other by tissue paper. This arrangement facilitates the rapid changes of polarity in the plates. This tube is terminated at its two extremities by two thick clamping discs which are made to compress the others lsterally, and the copper discs of the working coil occupy the two compartments at the extremities of the cylinder, as seen in Fig. 5. Under such conditions as these the resistance of the generator is small, and permits of great subdivision of the current in multiple arc; nor is there any insulation to be burned, and it is even possible, in case of the deterioration of the bars, to renew them easily, for they are simply screwed against the copper discs corresponding to them. In the new disposition adopted by Mr. Edison, the field magnets lie horizontal instead of being placed in the vertical.

Fig. 7 represents the whole machine as now actually working in the Palais de l'Industrie.

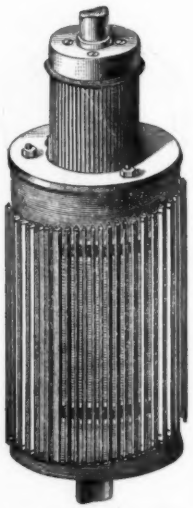


Fig. 6.

We have described the generating machine before completing the description of the system of distribution of the current, because we ought to speak of the system of control used in making the current uniform when its intensity has been modified by a variation in its distribution; that is to say, following after a variation resulting from the unexpected suppression of a certain number of lamps in a part of the system. The necessities of this system are easily understood, if we consider that this suppression can lead to a greater or less increase in the intensity of the current feeding the remaining lamps.

In France several systems have been

devised to obtain an automatic regulation, but in America, it seems, it is preferred to effect this by the intermediation of an appropriate controlling agent.

In this system, in whose general arrangement we see, in Fig. 8, the current which feeds the lamps furnishes a deviation at the machine *cc*, which enters an electric dynamometer, after having gone through a resistance of 180,000 ohms. The electro-motive force should be about 110 volts, and a difference of one volt should correspond on the scale of the indicating apparatus to three divisions; consequently, for each observed increase of intensity a resistance capable of compensating for it should be introduced into the circuit. Mr. Edison has established a circular commutator *e* with bobbins of different resistance, which permits of an increase of resistance, not in the lamp circuit, which would lead to a loss of work, but in the circuit of field magnets, which weakens their action on the working coil. From the central station also, the condition of the current affecting the lamps can be controlled by means of a testing photometer, which enables us to see how much the intensity of the current must be diminished or increased to correspond to a given luminous intensity. For this purpose the photometer is

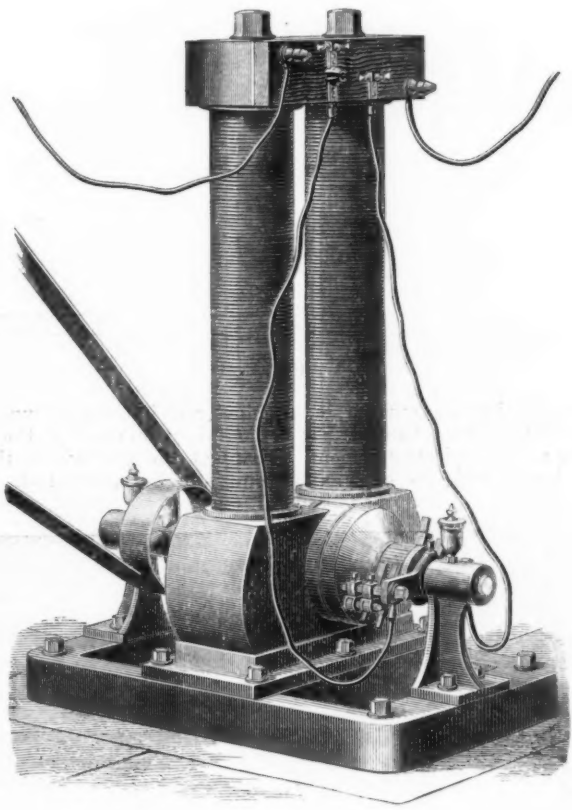


Fig. 7.

mounted on a little railroad, placed in a dark chamber; under and in front of it is placed a scale, arbitrarily divided, so as to indicate immediately the candle

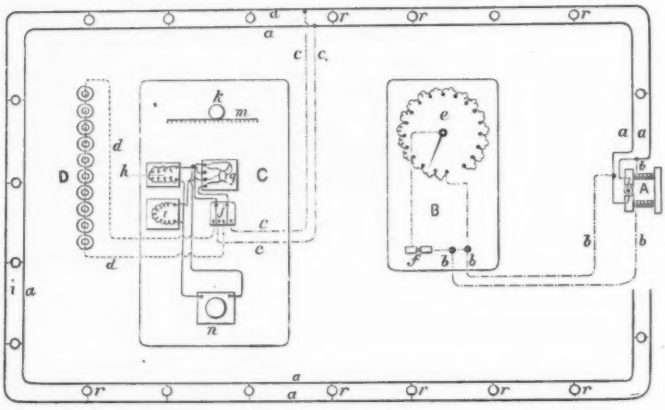


Fig. 8.

power furnished by the current in its normal condition. The left side of Fig. 8 indicates the manner of arrangement of the testing bench, with the explanatory

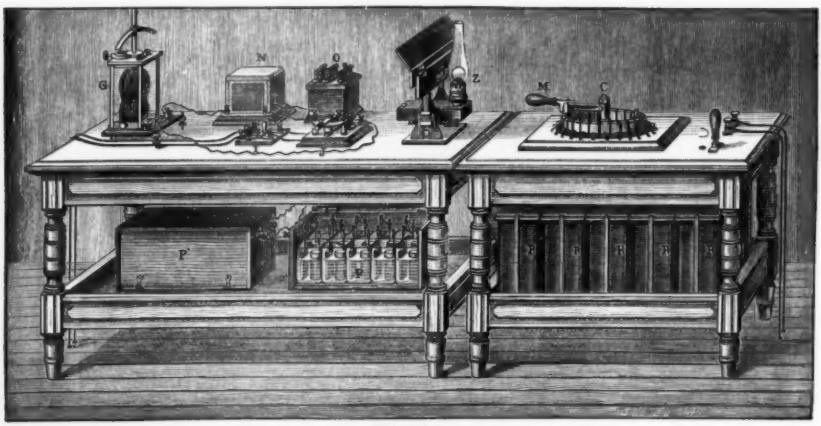


Fig. 9.

able at the bottom of the figure. Fig. 9 shows it in perspective. The manner in which derivations are taken on the principal conductors merits especial mention. The conductors are composed of two rods of copper of hemi-cylindrical form, flat on one side and round on the other, which are enveloped in cylinders of insulating material, contained in small wrought-iron pipes, which are buried under the streets. To take a derivation the cable is laid bare at the spot where the branch circuit is to be established. The two conducting rods (coming from the main conductors) are cut and bent outwards a n introduced into a clamp where they a r soldered to the house wires, as shown in Fig. 10; but in order that no harm can be

done by two strong currents, one of these communications is made by intercalating a lead wire in the branch circuit, shown at the bottom of the figure, and which,

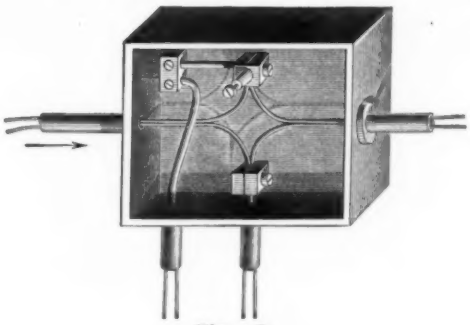


Fig. 10.

by its fusion, interrupts the circuit. This is what is called in America a "cut off;" and in this way it prevents deterioration. The box is then hermetically closed and covered with an insulating coating. In the figure the branch wires are shown

the lamp supports and the lamps themselves are disposed. As has been seen, they are formed of glass globes of ovoid form, cemented into copper sleeves by means of plaster and screwed into cylindrical cavities terminating the supports. These are a kind of arm which can be adapted to brackets or chandeliers, or be arranged around the walls. In the last case, the arm as is shown in Fig. 11, carry.

Fig. 11.

double, but it is evident that they could be single.

We said that all arrangements had been made to make the system a perfectly practical one, and of that we will soon be able to judge. Let us examine first how two articulations, A and B, and commutations are made by two plates of the hinges which are insulated, and in whose circular part two springs press, as seen in Figs. 12 and 13. Connections of the conductors with the lamp, as we have indi-

cated above, are made by a lead wire (cut off) which may melt and interrupt the circuit in case a too great quantity of current should endanger the lamp.

In these brackets, as in the three branch chandeliers, represented in Fig. 14, keys have been introduced which allow the extinction of the lamps separ-

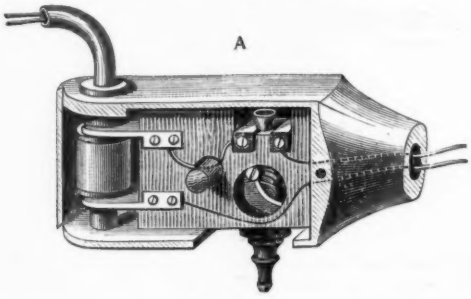


Fig. 12.

ately or together, without causing any spark of the point of rupture or any danger of fire. The movement of the key *a*, as shown in Fig. 12, breaks the contact by means of a conical stopper which terminates the screw of the key, and which, when separated from the two plates, through which the current passes when the stopper is in contact with them, breaks the circuits at the points and on

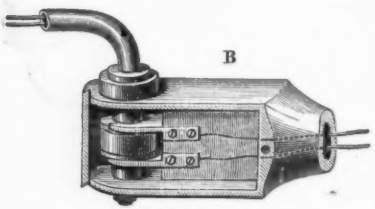


Fig. 13.

a surface of sufficient extent to greatly diminish the spark at the point of rupture.

The lighting of the two salons of Mr. Edison at the Exposition is done by 16 small chandeliers like the above, two grand crystal chandeliers and 80 brackets.

The effect is very beautiful, the steadiness being as complete as could be desired, and if, as I have been assured, the price of this kind of illumination is lower, light for light, than gas, it may be considered that the problem is on the eve of solution, for Edison's system of electric lighting is placed in the same condition as that of gas. He avoids the presence of machines in separate houses, which always are in the way, and which, by their very nature, require care and management not to be obtained from ordinary servants.

As a complement to his system, Mr. Edison has constructed portable chandeliers, represented in Fig. 15, and a current regulator shown in Figures 16 and 17, which permits of reducing the light in any desired proportion. It is a carbon rheostat, composed of carbon pencils of different sections, which, as the current passes through one or the other, allows any desired intensity. The apparatus is enveloped in a cylindrical cover, pierced with holes to allow of the escape of heat, and surmounted by a lamp which indicates to the eye the desired degree of luminacy. It is worked by a disc, shown separated in the lower part of Fig. 16, and which can be turned so as to bring a contact spring on any one of the supports of the carbon, whose position is indicated by an index and divisions engraved on the base of the cylinder.

But what is most interesting of all in those accessories of Mr. Edison's system, is the meter which determines the amount of electricity consumed by the lamps. There are two kinds, one automatic like a gas meter, the other requires weighing. They are, however, both founded on the same principle, that is to say, in the estimation of work by the

weight of a copper deposit produced by the current used. We will describe these two interesting pieces of apparatus hereafter, and give drawings of them; today we must be content with only mentioning the principle involved.

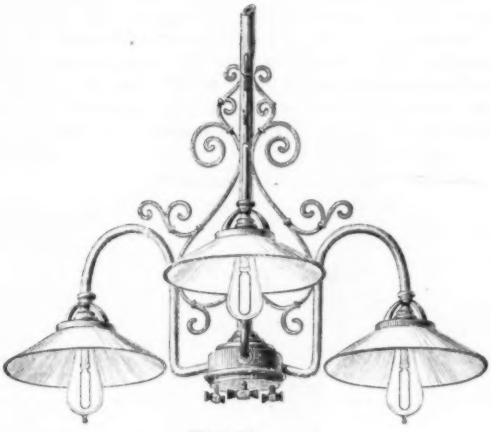


Fig. 14.

Fig. 15.

Imagine a balance having at the extremities of the beam two cylindrically rolled plates of copper forming two electrodes. Let us admit that these two systems of electrodes, which plunge into two vessels filled with a solution of sulphate of copper and furnished with fixed electrodes, are traversed in an inverse direction by the current employed, and which can cause the balance to operate under a given weight of copper deposited from the solution. It is easily seen that the movement brought about by these conditions can set in motion a current re-

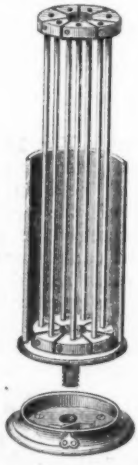


Fig. 16.

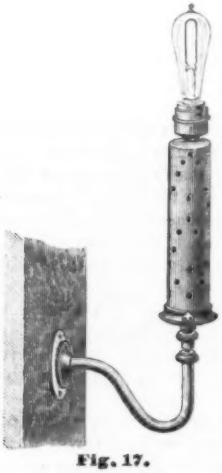


Fig. 17.

verser, which can change the conditions of the deposits in such a way that the electrode, covered with copper, is transformed into a soluble electrode, while the one which was originally in that condition becomes the reducing electrode. From this time on an oscillating motion of the beam of the balance is established, and more or less frequently repeated, according to the rapidity of the formation of deposit, that is to say, according to the intensity of the current. As the same movement can bring about the passage of a derived current (taken from the total current) across a special electro-magnet, which commands the movement of a counter, it is easily seen (after the determination of the number of Amperes corresponding to the weight of the deposit, which produces the oscillation of the balance) what is the quantity of electricity consumed.

The realization of this idea has necessitated some electro-magnetic arrangements, which we will describe in detail when we get the drawings of the apparatus.

The other system is more simple, consisting of two voltameters of sulphate of copper, whose electrodes can be easily taken out and weighed, as the work done can be calculated from the weight of copper deposited. One of these voltameters is open to the subscriber, the other is kept closed by the controller. Resistance bobbins introduced into the circuit corresponding to these resistances, permits of the employment of greater or less periods of registration.

A small incandescent lamp placed beneath the apparatus, and which can be thrown into circuit by a simple metallic thermometer, prevents any danger of freezing in extremely cold weather.

There is another application of Mr. Edison's light, which can be seen at his exposition in a model intended for lighting galleries in mines. In this arrange

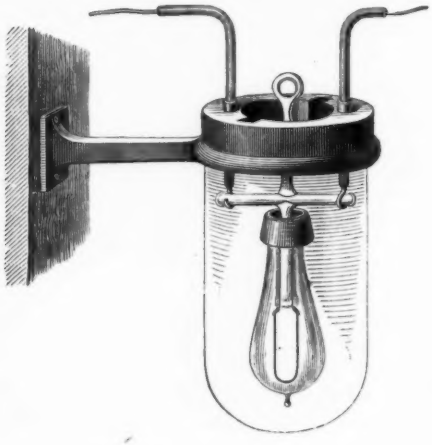


Fig. 18.

ment, represented in Fig. 18, the lamp is introduced in a glass receptacle filled with water and held in suspension. Communication of the apparatus with the circuit is arranged in such a way that the points of contact are covered by water, which avoids any danger of explosion in mines infested with fire damp.

To give an idea of the application of Mr. Edison's systems, we have represented in the large engraving accompanying this article, Fig. 19, the interior of a parlor lighted by the small chandeliers previously described. As is seen, the electric light is projected downward, the best arrangement for reading and writing. This method seems to be preferred by Mr. Edison, but as can be seen above described that all styles of illumination can be produced with this kind of light,

analogous to that obtained with candles or gas jets, it is simply a matter of taste.*

Mr. Edison's lamps are not alone employed in the two salons reserved for him, they are to be found in various places throughout the great nave, notably at the exhibits of Messrs. Heilman, Ducommun et Stienben (of which we gave a drawing in a previous article) and at the exhibit of Messrs. Sautter and Lemonnier. At these two places the currents are furnished by two Gramme machines, type A, and each one lights about 40 lamps. Now that Mr. Edison's great machine (a drawing of which is shown on frontispiece) has arrived at the Exposition, it will be possible to obtain, with the incandescent system, illuminations of greater magnitude. The landing of the great staircase will be lit in this way. It is proposed to accomplish this by means of a crystal chandelier of 144 lamps, and of others furnished with 25 lamps each, to be hung from the different panels, and of girandoles standing on the 16 pilasters of the staircase. This will produce an enchanting effect and a brilliant illumination. I am not quite sure that this mixture of arc and incandescent lights is a happy thought. It is evident that the latter destroy the effect of the former, and might lead one to believe that the luminous intensity of the incandescent lamp is less than it really is. Again, the difference in the color of the lights is so contrasted that many persons who reproach the electric for its ghastly aspect, find it too red in incandescent lamps. It is evidently an effect of contrast, for the light of incandescent lamps is whiter than that of gas jets, which, nevertheless, these same people find very agreeable. If required, incandescent lamps can give a dazzling white just as well as the others; it is only necessary to employ a stronger electrical intensity, then they lose their peculiar qualities, that of giving a soft light which does not fatigue the eye and of an easier and more complete subdivion.

It is certainly very difficult to satisfy everybody, and that many persons hardly know what they do want; above all, when the effects of contrast momentarily impair the power of judging correctly. On the other hand, there are certain fault-finding spirits who are never satisfied with anything; witness the author of that incomprehensible article that recently appeared in a certain journal, who pretended that only discordant sounds and puppet-show voices could be heard in the telephones from the opera. The author in question who could perpetrate such an enormity must have had his ear as sick as his humor. The crowd passing every evening before the telephone rooms at the Exposition, is the best proof of the inanity of such judgments, and by this can once more be seen the value of the scientific lucubrations of certain political journals.

The same thing happens with the electric light, and quite a number of persons who, without previous examination, and without being of the same opinion two days consecutively, come to us and disparage electric lighting. It is certain that new inventions have great difficulty in coming to light and in succeeding, above all when they are opposed by rival interests. but when they are really good they triumph in time over all obstacles.

We would like to give some information about Mr. Edison's new machines, but as they are not yet put up we reserve the description for another time; we will only say that the steam engine was constructed especially for this application, that it makes no noise, and that the dynamo-electric machine forms one of its integral parts. The field magnets of this latter-mentioned, in place of being vertical as in the model represented in Fig. 7, is horizontal, and the dimensions of the machine itself are much larger.

The steam engine, which works the machine, is of peculiar construction, and the speed of rotation which is communicated to the working coil is 350 turns a minute. This is not a very great speed, but the armature is very heavy, weighing, as we are told, over three tons and a half. The magnetic field in which it turns is formed by three powerful electro-magets, united so as to form but one at their extremities.* In the salon of Mr. Edison are a collection of photographs, among which may be seen some of the manufactures where the enormous amount of

* For want of time the engraving referred to has not been reproduced. The idea is shown in Fig. 14.

* For description of Steam Dynamo (frontispiece) see end of article.

material required in these installations is constructed. As we have been assured, one of these turns out 2,000 lamps a day, giving occupation to 150 persons. In accompanying drawings and collections can be seen methods of glass blowing, the carbonizing of the filaments intended for incandescence, the vacuum pumps and the mounting and packing of the lamps. The pumps referred to are set in motion by dynamo-electric machines.

From all this, we see Mr. Edison's system to-day is completed, perfectly studied out in all its parts, and that nothing more remains to be done, but to introduce it on a great scale.

TH. DU MONCEL.

[Note by the Translator.]

DESCRIPTION OF EDISON'S STEAM DYNAMO.

(*See Frontispiece.*)

Peculiar to the Edison system is the idea of connecting an engine of great power directly to the armature shaft of a single dynamo, capable of absorbing the full power of the engine, and of economically converting the same into electrical energy for distribution to the lamps and motors. To obtain the requisite electrical pressure, and avoid the use of magnets and armature of a weight and size which for mechanical and commercial reasons would be excessive, the engine is so constructed as to maintain a speed of 350 revolutions. A boiler pressure of 120 lbs., made absolutely safe by the use of approved sectional boilers, the high speed, and variable cut-off valve, and manner of constructing the engine makes this method of generating electricity absolutely safe and economical, and the uniformity obtained in regulation of speed insures a corresponding steadiness in the current and therefore in the lights which it supplies.

The following approximate summary of weights and dimensions of various parts of the latest "steam dynamo" constructed will give an idea of its total size and power.

Cast-iron sole plate, in one piece, upon which dynamo and engine are placed, and pillow blocks, 9,600 lbs.; Magnets, complete, 24,500 lbs.; Armature, complete, and shaft, 8,500 lbs.; Engine, 10,000 lbs. Total weight, 44,600 lbs.

The total weight of copper on armature and magnets is 3,600 lbs.

Principal dimensions: Sole plate $12\frac{1}{2} \times 8\frac{1}{2}$ ft.; length of magnets, 8 ft.; length of armature (commutator makes additional length of 9″) 5ft.; diameter of armature, 28″; Engine cylinder, $11'' \times 16''$; capacity, 2,400 gas jets.

GASEOUS FUEL.

From "The Building News."

WE have so long been accustomed to regard coal-gas merely as an illuminant, that it requires some effort to familiarise ourselves with the opinion which is daily gaining ground, that gas, suitably prepared and consumed in furnaces and stoves of proper construction, is among the best and cheapest kinds of fuel. One of the foremost and ablest advocates of the employment of gaseous fuel is Dr. Siemens, whose name is justly honored by all students of science as the inventor of the regenerative furnace, and the pioneer of the employment of electricity for illuminating purposes. Dr. Siemens has recently urged the preparation of two kinds of coal gas which he proposes should be distributed in separate mains, and be each of them specially adapted for the particular use to which it is to be applied. The gas given off from the retorts at the beginning and end of the process of gas-manufacture is far less rich in illuminating qualities than the gas expelled during the other part of the distillation, and the doctor has pointed out that by collecting the gases evolved at the commencement and close of the operation, and separating them from the remainder of the gas, it would be easy to obtain from, say, one ton of coal, one-third of illuminating-gas of high quality, or about 3,520 cubic feet, and two-thirds heating-gas, 7,040 c. ft. In London and many of our large towns it would scarcely be necessary to provide any additional mains, as, owing to competing companies, or the extension of the supply, many of the streets already contain a duplicate set of pipes. But even if it

became necessary to lay fresh mains, to make new house connections, and to provide a second meter to each house, the advantages of the plan proposed by Dr. Siemens would, we think, repay the additional outlay required. The cost of cheaper and less perfectly purified heating-gas might be kept as low, probably, as 1s per 1000 cu. feet, while the pure and high quality of the illuminating-gas might fairly enable it to be charged for at the rate of ,say,5s per 1,000 cu. ft. We need not, for the present argument, suppose that the heating-gas would be distributed without any attempt at purification, for it would certainly pay the gas company to take from it certain impurities which now constitute a considerable source of revenue, and amply repay the cost of their extraction. We have reproduced the stock arguments of gas managers against the plan propounded by Dr. Siemens, in order to show that though at first sight it might appear that there are considerable difficulties in the way of such a scheme, they are by no means insurmountable, and could readily be overcome if needs be. The main obstable to any attempt at progress at the present time is the comparative insignificance of the demand for gas for any other purpose than that of lighting, and the strong position of the gas companies in the absence of any serious competition. We may assume that at the present time each ton of coal carbonized yields about 10,500 cubic feet of coal gas. This volume of gas, sold as at present for 3s. per thousand cubic feet will yield 31s. 6d. to the company. They have no inducements to split up this gas, even if a brisk demand arose for cheap heating gas, into, say, 3,500 cubic feet of 18-candle gas at 5s. per 1,000 feet, and 7,000 cubic feet of heating gas at 1s., for they would obtain only 24s. 6d. for the same volume of gas. Even if we take the best possible case, and assume that the total yield is broken up into 7,000 feet of 16.25-candle gas at, say, 4s.,=28s.; and 3,500 feet of heating gas at, say, 1s. = 3s. 6d.; total, 31s. 6d., the company only gain the same price as at present, and they have to undertake a double distribution. From the experiments of M. Ellisen, of Paris, it would appear that the latter case represents the most favorable results to be obtained by splitting the gas into two qualities. When half the total volume of each kind of gas is obtained, the lighting gas is of 16.78 candle power. It is worthy of notice that even the very high qualities of gas do not actually contain more than 6½ per cent. of illuminating constituents. In ordinary gas, such as that supplied in London, in each 100 cubic feet there are only four which actually yield light; the remaining 96 cubic feet are chiefly heating gases, which burn with a colorless flame. We do not wish to make out that the gas could be used without these heat-giving constituents; indeed, they have a most important office to perform in raising the temperature of the flame, in order to permit of the perfect combustion of the hydrocarbons. We only draw attention to this fact in order to show what a relatively large proportion the non-lightgiving gases bear to the illuminate—viz., about 24 to 1.

But when cooking and heating by gas and the employment of gaseous fuel for manufacturing purposes comes to be a little better understood, we very much doubt whether even the cheaper form of coal gas, prepared, as at present, and which we have assumed might be sold at 1s. per thousand cubic feet, will ever become the fuel of the future. Heating gas of very good quality, and in every way well adapted for domestic and manufacturing purposes, can be obtained at an infinitely less cost, and with a far cheaper description of plant than the gas which is distilled from coal in retorts. To this cheaper gas the term "water-gas" has been somewhat improperly applied, and such gaseous fuel as this can be prepared on a large scale at little more than 2d. per thousand cubic feet, with a fair margin of profit. Concerning the manufacture of water gas, we need say no more here than that there are numerous plans, all more or less efficacious, for decomposing water into its two gaseous elements, hydrogen and oxygen. By the best of the contrivances which are employed for this purpose, it becomes possible to effect the separation of these gases, and to cause the oxygen at the moment of its liberation to combine with a volume of carbon, producing the best form of gaseous fuel obtainable from coal—to wit, carbonic oxide gas. In the ingenious apparatus which has been

patented for the manufacture of this gas by the Dowson Economic Gas Company, water contained in a small boiler is converted into steam, and this steam is superheated in iron subes; a jet of the high temperature steam thus obtained is then passed into a furnace containing a deep layer of anthracite coal. The steam, acting on the principle of the injector, is made to carry with it an adequate supply of atmospheric air, and the red-hot coal at once decomposes it into its gaseous elements—a very copious evolution of gas suitable for heating purposes is thus effected—and the gas may be purified by passing it through a layer of spongy oxide of iron. The yield of gas is in the ratio of 1,000 cubic feet to each 12 lbs. of coal added to the furnace, and 180,000 cubic feet can be readily obtained from one ton of anthracite coal. This gas has a calorific power equal to about $\frac{1}{3}$ that of coal gas, so that, in round numbers, we may assume that each ton of coal will yield, by this treatment, an amount of gaseous fuel equivalent to that obtained from five tons of coal carbonised on the present system. But gas made by the decomposition of steam has no tar, no ammonia, and cannot possibly burn with a smoky flame; indeed, there can be no deposition of soot, even when a cold metallic surface is exposed to the flame. Moreover, the foul-smelling hydrocarbons which cause the disagreeable smell in ordinary coal gas, and which have led to many difficulties in using gas for cooking purposes, are entirely absent in the water gas. It will be quite possible for a few families living in adjacent houses to combine and to obtain a supply of this economic gas laid on to their houses in the same way as coal gas now is, and this new gas can then be employed in the kitchen, the laundry, the bathroom, and the conservatory, and the present use of coal as a fuel may be entirely abandoned. We are informed, indeed, that Lord Sudely has adopted the gas for all these purposes with complete success. We have still to mention that another important feature connected with this gas is the facility with which it may be carburetted or impregnated with illuminating constituents. This is assisted by passing it through a vessel charged with gasoline. The vapor of the gasoline is absorbed by the gas, which becomes thereby so much enriched as to yield a high standard illuminant, superior in fact to London gas. We should remember, in conclusion, the immense importance which the possession of such a gas implies when we require power for domestic or manufacturing purposes. In a gas engine of the "Otto" type, made by the Messrs. Crossley, this water gas can be used in the same way as coal gas now is, and the cost of each horse power is proportionately decreased. The actual cost of working, on an extended trial, with a $3\frac{1}{2}$ horse-power effective engine, has proved that one horse-power (indicated) perhour is obtained with a consumption of gas derived from 1-4lbs. of anthracite coal. When we contrast this result with the working of the largest and best steam engines, using 2 lbs. of steam, coal per horse power per hour, the gas engine has a large balance in its favor; but when we remember that with small steam-engines the common consumption of coal varies from 5lbs. to 6 lbs of coal per horse-power per hour, the advantage in favor of the gas engine and the new gas is too great to be long overlooked by those to whom cheap power is a desideratum.

DO STEEL SHIPS PAY?

"Nautical Magazine."

Mild steel has now been in use in shipbuilding a sufficient time to afford some material for a judgment as to its economical advantages as compared with iron. In a paper read before the Institution of Naval Architects in 1878, Mr. Martell estimated the saving in weight obtained by using steel instead of iron at 18 to 19 per cent., and his calculations as to the consequent gain were based upon that percentage. Lloyd's Registry allow a reduction in scantlings of 20 per cent., but it is obviously impossible to obtain the benefit of this in every case owing to the fact that both iron and steel are only rolled to certain sizes, plates, for instance, only graduating in thickness by exact sixteenths of an inch.

It appears certain that the actual saving of weight is much less than 18 per cent., but as to the exact amount of the ratio and whether it is sufficient to pay a good interest upon the increased cost, there is still room for much difference of opinion. Two valuable papers have been read upon the subject before scientific societies recently, one by Mr. Denny, of Glasgow, before the Iron and Steel Institute in May last, the other by Mr. Price, of Jarrow, at the autumn meeting of the Institution of Mechanical Engineers at Newcastle. Mr. Denny as a result of some few years experience in steel shipbuilding, is of opinion that steel ships are a profitable investment even at the present (which he believes to be but temporary) high price of steel; Mr. Price on the other hand, having gone into the question with a view to designing some steel ships, is so firmly convinced of their unprofitableness that he recommends all his clients to have iron vessels. It may be of some interest to our readers to have these two views of the question placed side by side with some of the facts and figures respectively adduced in their support.

Mr. Denny gives as the result of his experience in building steel ships, that the saving in weight varies from thirteen to fourteen per cent. only. He gives the figures for an iron spar-decked steamer of 4,000 tons gross, compared with those for a similar vessel built of steel. The iron purchased for the first amounts to 2,333 tons, the metal for the second is 2,030 tons, which gives a difference of just over 13 per cent. It may be remarked that there is less scope for the 20 per cent. reduction on scantlings in a spar-decked vessel than in a full three-decked vessel, for the reason that the scantlings are smaller, and for the same reason still less could be, as a rule, gained by building awning-decked vessels of steel. Of the 2,030 tons, there are required for deck houses, coal bunkers and other parts of the vessel which do not contribute to her structural strength, no less than 340 tons. In these no reduction is practicable; when made of iron they are as thin as is consistent with the necessary rigidity, and mild steel is less rigid than iron. Mr Denny also tells us that although mild steel has been used for forgings they have not seen their way to reduce the weight of these. It is thus the case that 381 tons of the metal are not subject to reduction at all. In the remaining 1,952 tons of iron, the reduction obtainable in practice is found to be 18½ per cent., but this reduction is in cubic contents only, and since mild steel is found to be 2½ per cent. heavier volume for volume than iron, the total weight of steel used in place of iron is 1,631 tons, which, with the indispensable iron upon which no reduction is practicable, gives the total weight of metal required for a screw steamer as stated at the outset. In this estimate the amount of metal paid for is taken; the actual weight in the ship is less than this by 9 per cent. in each case for waste scrap, and thus the increase in dead-weight capacity becomes 276 tons, that is, 7 per cent. upon the figures of the gross register tonnage. Mr. Denny states as the result of his experience that this rate is pretty nearly constant, that is, that the figures of the increased dead-weight capacity obtained by using steel in place of iron in the same design may be obtained by taking 7 to 7½ per cent. of the gross register tonnage. The net cost of the iron in the iron steamer would be at the present rate £14,500, and in the steel steamer the total cost of metal would exceed this by £3,574. The extra dead-weight capacity of 276 tons is thus paid for in construction at the rate of £13 per ton.

The next step is to consider what the value of the extra capacity would be. Of course, this would vary with the voyage. Mr. Denny selects the Indian trade and estimates that the extra net gain would in two years nearly pay the extra cost of the steel steamer. "That this argument," he says, "is appreciated by the great steam companies is proved, in the case of the London and Calcutta trade, by the fact that all the latest orders of the Peninsular and Oriental Steam Navigation Company and the British India Company, the two leading lines of steamers upon that route, have been for steel vessels. At the present moment these companies are building between them nine steel steamers of over 4,000 tons gross."

We have not space to follow Mr. Denny in a comparison of an iron steamer with one built of steel of slightly smaller dimensions, but which, in conse-

quence of the smaller weight of the structure, is able on a less displacement to carry the same cargo. In this case a considerably larger sum is paid for the smaller vessel, but the gain is said to be a decrease of draught and a smaller taxable tonnage. We do not think, however, that the best comparison can be made in this way. If two vessels have exactly the same dimensions, their expenses of propulsion, &c., are the same, and in this case it is possible and easy to set off on the one side the extra prime cost and on the other the extra earning capability, both due merely to the substitution of one material for the other.

Mr. Price, of Jarrow, who may to some extent be taken to represent the practical experience of Tyne shipbuilding, comes to an entirely different conclusion from that of Mr. Denny. The figures given by him, however, did not represent the case of a steel vessel actually built, but only a comparison of the weight and cost of an existing recently finished iron steamer with what a vessel of the same dimensions would have been, if built of steel. The gross tonnage taken was 2,285, and on this Mr. Price calculated that a gain in dead-weight capacity of 118 tons would be purchased by an additional expenditure for the dearer material of £2,760, or at the rate of £23 8*s.* per ton. Mr Price thus concludes the comparison:—

"Now we may assume with perfect safety that the iron steamer, such as is described, could be built and equipped ready for sea, including all cost of engines, boilers, &c., for £10 per ton of dead-weight capacity. This would make her price for 3,235 tons dead weight capacity to be £32,350. Add to this £2,760 for the extra cost if the vessel is built of steel, and we have £35,110 as the cost of the steel vessel for a dead-weight carrying capacity of 3,353 tons. This shows the average cost per ton of dead weight to have been increased from £10 to £10 9*s.* 6*d.*, or an increase in the entire cost of $4\frac{3}{4}$ per cent." This way of considering the question appears to us to be unfair as regards steel, for the reason that however the cost per ton of dead-weight capacity may be useful in comparing one iron ship with another, it is manifestly erroneous in comparing a steel with an iron ship of the same size. The working expenses of the two ships, including the coal consumption for a given speed, would, since they are of exactly the same design, be equal; hence the price per ton, at which the increase of dead weight is obtained by a saving in the weight of the structure, is paid for by so much clear gain in freight subject only to extra charge for insurance of the extra value.

Mr. Price also urges that in a steel ship it would be necessary to have a larger ballast tank because of her lighter structure, and this tank involves again additional expense, and its weight somewhat detracts from the former assumed saving of weight. There is, further, he says, the disadvantage that the measurement capacity of the hold is decreased by the increased size of the tank. It was very properly pointed out, by a speaker in the discussion upon the paper, that it would not really be necessary for the sake of proper stability, to immerse the steel ship when in ballast as deeply as the iron one. The decrease in weight proportionately is as much in her upper works as below, and an inconsiderable addition to the ballast tank would be all that was necessary to compensate for the slightly larger actual decrease in weight below over that in weight above the center of gravity.

In two vessels of extreme types, but of about the same size, the net cargo capacity may in one case be two or three times that of the other, hence an addition of so much cargo capacity free of all drawbacks, would in the latter case be worth two to three times as much as the former. In the sailing ship, or in the slow steamer running short voyages, the gain might not be worth the extra cost, while in the fast passenger ship, especially in the case of very long voyages, it would be worth many times the money paid for it.

The present price of steel plates and angles for shipbuilding is still more than 50 per cent. in excess of that of iron, and there appears no probability at present of much material decrease. One great reason for the difference in price is the severe testing to which the steel is subject. This is, however, as we have often urged in these pages, a necessary concomitant of the reduced scantlings; without it the extra quality in the material cannot be secured to compensate for the reduced size.

OUR PROGRESS IN MECHANICAL ENGINEERING.

THE PRESIDENT'S ANNUAL ADDRESS.

American Society of Mechanical Engineers, New York Meeting, November 3d, 1881.

By ROBERT H. THURSTON, President.

GENTLEMEN OF THE SOCIETY:

It is impossible, in the limited time that must be allotted to the President's annual address, to do more than glance rapidly over the broad field of mechanical engineering, selecting for study the more prominent and more important departments, and very briefly noting what is their present state, and how far improvement has progressed during late years. The direction of movement to-day becoming known, and the character of the difficulties presenting themselves being ascertained, the way in which accelerated progress may be rendered possible, becomes more easy of detection. In many cases we shall find ourselves able to decide precisely where to look for such progress, and, in all directions we shall find our exploration interesting, gratifying, and profitable. We will first examine those departments which supply us with our materials.

In that field to which we are apt to give too little consideration, notwithstanding the fact that it lies at the base of all our work, a field which—formerly cultivated by many of the greatest men that our profession has known—is now too generally neglected, while more seductive but less fruitful, and, on the whole, less immediately important departments are overcrowded with able workers, in that of the materials of construction, we are making steady progress on every side.

We are everywhere giving up the use of that expensive and perishable material, wood, and the weak and brittle minerals, and are substituting for them iron and steel.

Iron is slowly but steadily and inevitably being displaced by steel. Cast iron in small parts is less and less used as steel castings become more and more reliable, and especially as the art of making drop-forgings of larger size and in more intricate forms is perfected. Sheet steel, very low in carbon and other hardening elements, is becoming, year by year, more generally adopted in boiler-making, not because of its greater strength, for the stronger grades are always rejected by the experienced boiler-maker, but because of the greater uniformity, ease of working, freedom from cinder, and the durability of those grades which are well suited to such use.

A tenacity of *less* than 65,000 pounds per square inch (4,550 kilos. on the square centimeter) and great ductility are demanded for this work.

In rods and bars, and for sheets to be used where mechanical forces only are present, we are getting steel which, with a tenacity of 80,000 pounds per square inch (5,624 kilos. per square inch), stretch 25 per cent. before breaking, and we are sometimes given a grade very low in carbon, but high in manganese, which has ten per cent. higher tenacity and equal ductility. In fact, we are apparently coming to a *manganese steel* as the metal for use in general construction.

In making alloys I have been able to show the existence of an alloy of copper, zinc and tin of maximum possible strength and to point out approximately its composition, and my discovery has been confirmed by other investigators, who have independently hit upon alloys closely related to this "maximum metal," and possessing properties of hardly less value. We now know that by carefully proportioning the constituents, by proper fluxing the alloy, and by special mechanical treatment we may obtain brasses and bronzes having strengths undreamed of by earlier engineers. Tenacities of from 75,000 to over 100,000 pounds per square inch (5,273 to 7,030 kilos. per square centimeter) have already been attained.

The introduction of special alloys having extraordinary strength and uniformity of composition, as the phospor

bronzes, manganese bronzes, and sterro-metal, indicate that workers in metal are beginning to enter upon the path long since opened to them by scientific research.

Dr. Fleitman's discovery of a method of making nickel malleable, and capable of welding, and his similar improvement of commercial cobalt by the use of magnesium, is in itself important, and promises to lead the way to further progress.

In the application of the materials of construction we are learning some exceedingly important facts, the most valuable of which relate to those most "precious" of the metals, iron and steel.

The effect of variation of temperature in the annealing of these metals, and in the hardening and tempering of steel has long been known. That annealed and unannealled wire differ widely in tenacity and in ductility, that very "mild" steel and good iron are softened by the very process which gives hardness to steel, are long familiar facts, and it has probably been long known to many engineers that there exists a critical temperature, probably definite and fixed for each grade, at which the hardening of steel occurs. Passing this point in cooling the metal takes on its temper, but variations of temperature on either side that point produces no observable effect on its condition however rapidly they may take place. This critical temperature has now been identified in certain cases, and may prove to be nearly the same for all steels.

The process of "cold-rolling" has long been known to engineers as an exceedingly valuable method of enormously increasing the strength and elasticity of iron. We have now learned that it is applicable to the soft steels, and I think it will become certain ere long that its full effects may be obtained at any temperature below that critical point which defines the limit of molecular stability, as I have just stated it, in steel.

Lauth's process has been applied with equal success to certain alloys of copper and tin, by Sears, in the United States, and later by Rosetti, in Italy, and very extensively and successfully by Uchatius, in Austria. Tobin has cold-rolled bronzes, approaching the "maximum" alloy in composition, and has attained tenacities exceeding 100,000 pounds per inch (7,030 kgs. per square centimeter).

The radical distinction which is observable in the behavior of metals under stress, and which leads to their division into what I have proposed to call the iron class and the tin class—in the variation of the normal line of elastic limits by intermitted stress—is becoming generally known. Engineers are beginning to perceive that that exaltation of the normal elastic limit, which is observable in the former class, is probably a valuable quality, one the existence of which may prove to justify the use of smaller factors of safety than have hitherto been thought allowable; and this leads to less expense in stationary structures, and to the elimination, to some extent, of stresses due to the inertia of moving parts in machinery. The conclusion reached by many engineers, that moderate static loads may be sustained indefinitely by iron and steel are also to this extent sustained.

On the other hand we are led to the observance of more than usual caution in the use of metals of the tin class, including most of the brasses and bronzes, and to the use, in such cases, of higher factors of safety than are demanded in constructions of iron and steel.

Preliminary straining to secure an elevated initial elastic limit with relief of internal stress is likely to be of service in the applications of iron and steel, as *e.g.* by cold-rolling, by "frigo-tension" and "thermo-tension" and by wire-drawing, while it proves to be probably less effective with other metals.

The experiments made for the Prussian Government by Wöhler and Spangenberg during a period of fifteen years, and which have now been concluded eight years, are just becoming known to practising engineers, and Wöhler's law, Launhardt's and Weyrauch's analyses of results are found valuable checks upon usual methods of proportioning iron parts of structures. It is becoming known that not simply the load to be applied, but the frequency and the method of its application, and the condition of the structure as determined by earlier strains, must be considered in settling upon its dimensions, and upon the magnitude of the factor of safety.

Neverthless, in ordinary work we find that, as experience has taught us, these quantities are well covered by the factors of safety that have become generally accepted. The great value of these researches, and of the many others of the same kind which have been made in every part of the civilized world, is found to come of the ability now conferred upon the engineer to proportion with confidence parts exposed to exceptionally great and unusually variable stresses.

Perhaps the most important advance made in the use of materials in engineering has been the general introduction of systematic inspection, and of careful test of all materials used. Such inspection and test is now demanded by every well-drawn specification, and is carried out usually by trained and skillful inspectors.

The Pennsylvania R.R. Co., the Bethlehem Iron Co. and other well-managed establishments have even organized complete departments devoted to the examination and test of all materials offered them, and often find that a single investigation repays the whole cost of the department for a period of years. So essential is that system found to be that I am frequently called upon to advise in regard to new "laboratories" in all parts of the country in which iron, steel, lubricating materials, and other supplies of value are to be systematically examined before purchase. This is not a mere matter of dollars and cents however. Every engineer who has experienced the anxiety which comes of uncertainty in regard to the character of the material of a structure, in which a single defective piece may cause the destruction of the whole with enormous loss of time, money, and, probably of life, will understand what good comes of a system of inspection and test that entirely relieves both conscience and pocket of responsibility and risk.

A method of inspection which, as I showed ten years ago, will safely determine the value of each piece, subsequently to be actually put into the structure or machine, is now slowly becoming adopted and we may hope that soon, we may confidently assert of each bridge over which we ride, of each machine upon the strength of which depends safety of life and property, that its every part has been proven, by actual test before use, to be perfectly safe. Now that the great testing machine at Watertown Arsenal, set up by the unfortunately defunct Board appointed in 1875 to test iron, steel and other metals, is at the service of the public, we may hope that such methods of test may hereafter become common, and that tests of full-sized parts of bridges and machines, made at private cost, may, to limited extent at least, yield the knowladge that that Board would have more systematically and at less expense have made familiar to engineers, had its life not been terminated at the very beginning of its labors.

I have to thank General Walker, the Superintendent of the Census, for many valuable data, and not the least interesting of all is the report of Mr. Swank, on the iron trades, of which I am supplied with an advance copy. I know of no better gauge of the extent and importance of the work of the mechanical engineer than the production of iron and steel. These metals are worked up by the mechanical engineer and the trades associated with the profession, and the consumption of the raw material is the truest measure of the magnitude and value of our work.

The growth of the iron manufactures of the United States have all occurred since A. D. 1700, when there was not a blast furnace in this country, and principally since the year 1794 when the first steam engine was erected in America, eighteen years after James Watt made the improvements that have given him fame, and that have given the world more wealth and comfort than had been accumulated during the many centuries of civilization historically known to us as preceding his time.

To-day, we have over 1,000 iron and steel works in the United States, employing $230,000,000 in capital, as against $122,000,000 in 1870–1871, producing 7¼ millions of tons of iron and steel, just double the production of 1870, and employing nearly 150,000 men. The value of all products is not far from $300,000,000, and wages amount annually to about $55,000,000. In ten years Massachusetts has increased her product 65 per cent., West Virginia, 104 per cent., Alabama, 800 per cent., nearly, Georgia, 125 and Tennessee 125 per cent.

Pennsylvania holds her place at the

head of the list, producing 3½ millions of tons per annum; Ohio makes one million, New York, 600,000, Illinois, 400,000, New Jersey, a quarter of a million, and other states smaller amounts.

Since the year 1870, we have increased the weight of pig metal from 2 to 3¾ millions of tons per annum, or 84 per cent.; rolling mills make 2½ millions of tons of rolled iron, an increase of two-thirds; the Bessemer steel manufacture has grown from less than 20,000 tons in 1870 to 900,000 tons in 1881; "open-hearth steel" is now reported at about 95,000 tons, and this is an industry which was unknown in this country in 1870. Of crucible steel, we make 70,000 tons—a gain of 150 per cent. in the decade—and its applications are extending wonderfully, day by day.

But Great Britain still remains at the head of iron-making countries, turning out 8 millions of tons of pig iron during the year, an increase of one-third since 1870, and the increase still continues. The weight of Bessemer rails made has reached above 700,000 tons, and of Siemens-Martin steel a quarter of a million tons per annum.

Germany and France exhibit similar gains in amount of iron and steel made, and other countries of the world follow after.

Even Italy, famous as the home of the fine arts, yet disgraced by her neglect of the useful arts—the country of beautiful art galleries and of uncomfortable homes—has produced about 300,000 tons of iron ore, of which a small amount is there worked into finished iron. The artistic sense of her people is even here seen, and her blacksmiths make architectural work in hammered iron which would have satisfied even Michael Angelo.

The introduction into open hearth steel making of the Pernot furnace with its revolving saucer-shaped hearth, and of the Ponsard furnace with its modernization of the ancient process, are the latest steps in the improvement of steel-making apparatus; and the dephosphorizing process of Thomas and Gilchrist, by permitting the use of hitherto condemned ores, will prove a grand step in the reduction of cost of Bessemer steel, which must hasten greatly that inevitable change which will, ere long, replace malleable iron by steel in all of its myriad uses. Good mild steel can at last be made cheaper than good iron, and we are now entering fairly into the "steel age."

This is the grandest of all the industrial revolutions that have affected the iron trades; although its influence upon the prosperity of the nation and of all civilized countries cannot be yet estimated, we may be sure that it will be hardly less observable, and that it will be of hardly inferior importance to the world, than was the introduction of puddled iron a century ago.

We are using steel in every department of our work, and that most remarkable of all its many grades, Whitworth's compressed metal, is now at last coming into commercial importance; and of it are to-day made shafts for the largest steamships and ordnance that has no equal in strength and endurance.

Any size desired can now be made in cast steel, and 100-ton ingots, shaped under 80-ton hammers, are the *pieces de resistance* of at least one European establishment.

The progress of art, directed by brain and sustained by energy, skill, and enterprise, is well illustrated by the changes which have taken place in our textile manufactures. According to Atkinson, a century ago one person in each family was compelled to work, day in and day out, nearly the whole year, to furnish home-spun and dress goods for the rest; to-day, such has been the progress in the introduction of mechanism and automata, that one day's work in the year will, on the average, be sufficient to enable each worker to supply himself with all needed cotton and woolen fabrics.

Speeds of cotton spindles have risen, during the two decades that my memory can follow the change, from 5,000 to 7,500 revolutions per minute. Looms then making 120 picks per minute make now, Mr. Webber tells me, as high as 160, and one hand takes charge of from 25 to 50 per cent. more work. The "Slasher" dresser does *ten times* the work of the old machine, supplying 400 looms in place of 40, and demanding the attendance of only one man and a boy, instead of two men and ten girls. Pickers handle a ton of cotton per day in place of a half or five-eights ton.

The cheaply made turbine driving

these mills has completely displaced the old costly vertical wheel, doing the work with less water and greater steadiness.

Its efficiency has risen from 70 or 75 to 80 and 85, and sometimes to 90 per cent.

When the last generation was in its prime our factories were in operation twelve or thirteen hours; "Man's work was from sun to sun, and woman's work was never done." To-day man works ten hours, and woman is coming to a stage in which she will work where, when, and how she pleases. Then three yards an hour was the product for a single operative; to-day ten yards per worker are produced. In twenty years the annual product in cotton mills has risen from 2½ tons to 3½ tons per annum per mill-hand; wages have increased 20 per cent., and the buying power of the dollar has risen in much more than equal proportion, thus adding 50 per cent. to the comforts and luxuries of working people, permitting an increased number of happy marriages and comfortable homes, setting free the child-slaves of the mills, and turning them into the schools.

Where one hand then drove forty spindles, he now manages sixty; and every seven of the more than ten millions of spindles in operation works up a bale of cotton each year and turns out a hundred dollars worth of product. This product is supplied to the most indigent of our poor at a small advance on the one and a half cents for labor, and equal sum for raw cotton, which are expended in the manufacture of the cheapest grades. A still more striking fact is the distribution of our cotton goods to distant countries. A single mill operative at Fall River, Lowell, or Providence makes each year cotton cloth enough to supply 1,500 of the people who pay her wages by sending her tea.

In regard to woolen manufactures we have the same story to tell. All machinery has been speeded up, product increased, labor diminished, costs lessened, and machinery given greater automatism and higher efficiency both in making ordinary goods and in adaptation to finer grades. The manufacture has had a healthy growth, and the product is daily competing more successfully with the best of imported goods.

It is, I find, difficult, perhaps impossible, to make an exact statement of the extent of recent progress in the silk manufacture in this country.

Power looms and automatic machinery have been introduced more slowly in this trade than in others. Yet progress has been made. New and improved apparatus is steadily displacing older forms; power machinery is taking the place of hand-worked machines—with some rapidity in mills working the coarser grades, and more slowly where the finest goods are produced.

The strength, durability, and finish of all kinds of silks are constantly becoming more and more nearly equal to the best imported. Indeed, the ladies assure me that some makes of American silk wear much better than any of foreign make yet seen in our market, and that several grades have a finish which compares favorably with the very best of European silks. In variety and in quantity of goods produced a steady gain is to be noted. The ingenuity of the American workman, aided by talent and experience, coming from the older silk-making provinces of Europe, seem likely to give to this manufacture a position of which its promoters may well be proud.

Mr. Wyckoff, Secretary of the Association, reports, June 30th, of the current year a production in the United States of nearly $35,000,000 in finished goods, by about 400 factories, employing a capital of $19,000,000 and over 30,000 operatives, whose wages amount to about $9,000,000 per annum. Good progress this for an industry often condemned as exotic, and one which has only become established within the remembrance of the majority of our members. A half million spindles, running often 10,000 revolutions per minute instead of 5,000 as a few years ago, and over 5,000 power and 4,000 hand looms make a large showing. Spinning frames occupy $\frac{1}{4\,0\,0}$th the space, and cost $\frac{1}{2\,0}$th as much per spindle as in the earlier days of the trade, and the cost of work has now become so small that $3.00 per pound spent in wages make silk costing $5.00 per pound into finished goods averaging $11.50.

In machine work generally the distinctively American idea of manufacturing as opposed to the old methods of making parts or mechanism in large numbers is steadily progressing, thanks

to the ingenuity of mechanics like our colleagues, Pratt and Whitney and others, in devising tools specially designed for the production of definitely limited kinds of work.

The same wonderful genius of invention which produced the Whitney cotton gin, the Blanchard lathe, our screw machinery, and the more wonderful card-setting machine has lately given us Sellers' automatic gear-cutter, the automatic turret-lathe, and a thousand and one machine tools hardly less remarkable in construction and efficiency.

Turning to the examination of the present condition of the railroad system of our country—that system which, binding State to State with lines of steel, is our strongest safeguard against political dissension and disunion—we find that changes are everywhere in progress under the direction of some of the ablest members of our profession.

It is now seventy years since Col. John Stevens, in his memorable correspondence with Dewitt Clinton, urged the adoption of a complete system of steam transportation on railways, and asserted that the time would come when "suits of carriages," as he said, would make their journeys, impelled by steam, with as much celerity in the darkest night as in the light of day, and stated that he "could see nothing to hinder a steam-carriage moving on its ways with a velocity of 100 miles an hour," and that he "should not be surprised" at seeing them propelled 40 or 50 miles an hour. His contemporary, Oliver Evans, wrote: "A carriage will start from Washington in the morning, the passengers will breakfast at Baltimore, dine in Philadelphia, and sleep in New York the same day."

But it was a generation later before these prophecies were credited; it was only when, fifty years ago, the introduction of railroads had an actual beginning.

To-day we have a hundred thousand miles of track laid down in the United States—we have about one-half of the constructed railroads of the world. Trains here and in Great Britain make 50 miles an hour on schedule time, taking water from the track, and receiving and delivering mails without stop. A speed of 100 miles—Stevens' maximum figure—has been many times attained. Locomotives are frequently built weighing 50 tons; 70 tons has been reached, and every builder of engines is ready to guarantee the performance of an engine to draw 2,000 tons 20 miles an hour on a level track. In coal consumption we have made some saving of late years. Three pounds of coal per hour and per horse-power is a usual power, and a consumption of 2.6 pounds (1.2 kgs.) of coal, and of 22½ pounds (10 kgs.) steam has been reported from recent locomotive tests.

The trapping of cinder and the reduction of intensity of combustion by extending grate area are late improvements. The time will come, and it should have come already, when the nuisance of flying dust and cinder will be unknown.

Comparative comfort has at last come to the weary traveler in our parlor and sleeping cars, and the greatest of all modern inventions in this department, the Westinghouse continuous brake and the Miller platform and coupler, have decreased the risks of journeying by rail to a merely infinitesimal quantity.

A train which, when at full speed, can be stopped within its own length is comparatively safe against the most serious of usual contingencies.

Steel rails have driven out iron, and this superior metal is slowly and surely taking the place of its defective rival in boiler and running parts. It is an interesting fact that, while Bessemer steel is used for rails, open-hearth steel is coming to be as exclusively used for all parts of the locomotive.

The efficiency of the late styles of stationary engines is illustrated by figures like these: Corliss obtains a duty, as reckoned from figures recorded by my assistant at a recent 12-hour trial of his last Providence pumping engine of 113,878,580, without reduction or allowances, and the average of several days trial is 112 millions. Leavitt gives me data showing a duty for months together of about 105 millions, and obtains a horse power with an expenditure of 16½ pounds of feed-water per hour at Lynn and 16.23 at Lawrence. His Calumet engine with wet steam and but 200 feet piston speed, demands but 18 pounds (8.2 kilos.), and the Hecla hoisting engine is credited with the wonderfully low figure—16 pounds (7.3 kilos.). This, by the way, is the more remarkable from the

fact that the jackets were disconnected. We thus sometimes meet with hints, apparently, that we may do better work with an underheated than with an overheated cylinder jacket. The performance of the West-side pumping engines at Chicago, giving a duty of nearly 100 millions with lower heads only jacketted is similarly significant.

This figure—16 pounds of steam per hour and per horse-power—may be put on record as the very best economy attained by our best engineers at the end of the decade 1870-1880. It is just double the weight which would be required in a perfect engine working steam of the same pressure at maximum efficiency. This leaves us still a fair margin for further advance in the construction of the engine. The steam boiler is at a standstill; there is but little margin for gain in economy, but a large gain in weight of steam supplied per pound of boiler may be expected when the tardily recognized advantage of forced circulation is secured.

Air and gas engines are here competing with stationary steam engines, and, so far as I can see, in no other field. The compressed air engine, the petroleum engine, and the gas engine are all just now coming forward. I have no figures that I can rely upon except for the gas engine, which sometimes consumes as little as 18 cubic feet of gas ($\frac{1}{2}$ cubic meters nearly), per hour per horse-power.

The solar motor proposed by Ericsson, the inevitably coming motor of some far-distant epoch, has, as yet, made no progress beyond the plans and experiments of the inventor.

I have nothing to report relative to either the development or the application of the theory of heat engines. The splendid labors of Rankine and the work of that most logical and classical, if less practical writer, Clausius, have so cleared the field that later investigators are driven into the exploration of minor departments of thermo-dynamics. The engineer is to-day seeking, with the aid of the physicist, to determine the facts and the laws governing the exchange of heat between the working fluid and its enclosing walls. This is for him to-day the greatest of the problems presented in this department.

The purely commercial aspects of steam-engine economy, familiar as they have long been to builders of expensive engines and to the more intelligent buyers have barely attracted the attention of engineers generally, and have, as yet, apparently been entirely overlooked by all having a scientific standing with, I think, the solitary exception of that greatest of modern scientific engineers, Rankine. A year ago, in debate, I called attention to the fact that economy in fuel was but one among the many items of expense incurred in the operation of steam machinery, and that it formed by no means the greatest part of such expense in certain cases. The inference at once follows that commercial economy, affected as it is by all these items, must be studied with reference, not to cost of fuel simply, but with a view to making total expense a minimum. Rankine called attention to this obvious conclusion many years ago, and a paper presented by two of our colleagues at the May meeting in Hartford, extending Rankine's work, and applying his approximately exact method to modern engines, showed that commercial efficiency is often made a maximum with very much smaller engines, and lower rates of expansion, than are found to give maximum economy of fuel. Such methods of determining size of engine will probably be generally adopted by engineers seeking the best interests of their clients. We are not, it is evident, to conclude, from the results of the application of the Rankine method of determining size of engine and maximum commercial efficiency, that we are always to lose so large a proportion of the gain obtainable by further expansion of steam. We conclude, rather, that the engineer must direct his attention to improvements designed to reduce these counteracting wastes. He must find methods of rendering the machine, including boiler, automatic, and thus of reducing cost of attendance; he must find ways of reducing first cost, as by increasing speed and making smaller engines do the work, as by finding ways of building cheaply, yet doing good work, and of making lubrication less costly, or of doing away with it altogether. Automatic firing, or "stoking," automatic feeds, and automatic cleaning apparatus are already in use, as well as automatic regulation of

the engine, of steam pressure, of point of cut-off, and of chimney draft. All these improvements, when once made successful and thoroughly reliable, will come in effectively to aid the engineer in this direction, as well as the more direct advances in progress in the direction of reducing back pressure and of checking cylinder condensation, of increasing steam pressure, superheating, and obtaining by the use of all known methods of high ratios of expansion at maximum efficiency. The engineer and the physicist working hand in hand in the future as they have in the past—or perhaps the engineer-physicist—will sooner or later, following the paths pointed out by Smeaton and Perkins, and in our time, by Corliss, Porter, and Leavitt, greatly reduce the now often broad margin between theoretical efficiency and commercial economy. When the engineer has once acquired the habit of gauging the value of an engine by the magnitude of its ratio of expansion at maximum efficiency, all this latter class of improvements will advance with increased rapidity, and when he sees that the magnitude of the ratio of expansion at maximum commercial economy is a gauge of his success in making steam power useful, the first class of improvements and of inventions will similarly advance, while we shall gladly approximate to mechanical perfection, and this progress will occur at a rate which will be measured by the approach of the two ratios of expansion to the same maximum, finally both becoming nearly coincident with the ratio of maximum efficiency of fluid for each given case.

The "compound" engine has become the standard type of steam engine in use on shipboard as well as for stationary pumping engines. We still hear occasionally intimations that a counter-revolution and return to the single cylinder type of engine may be expected, but that change is not observable. The direction and extent of recent advances in marine architecture are readily noted. The proportions of length of ship to breadth remain, as during several years past, about 10 to 1 or 11 to 1, about 50 per cent. greater than has been considered by some of the best engineers as that giving highest efficiency. The Great Eastern 680 feet long, of 83 feet beam, and measuring 25,000 tons displacement, still remains the largest ship yet built; but steamers are under construction for transatlantic lines 600 feet long, of over 50 feet beam, and fitted with engines of 10,000 indicated horse-power. A speed of twenty miles an hour in good weather throughout the voyage, making the distance from land to land in less than a week may be expected soon to become usual. Double hulls and transverse bulkheads will make these great vessels safe even against the shock of collision with an iceberg.

Steam pressure has gradually and steadily risen since the time of Watt, when seven pounds—½ atmosphere—was usual. To-day 6 atmospheres (75 pounds per square inch) is as usual, and 7 atmospheres (90 pounds) is often adopted. Such pressures have compelled the general introduction of the simplest form of steam boiler; the cylindrical tubular boiler with large flues beneath the tubes, in which the furnaces are formed. Strength of flues is obtained by the use of heavy plates, sometimes flanged at the girth seams. "Mild" steel is here slowly displacing iron.

I have had occasion to remark, that in ordinary practice increase of steam pressure with correspondingly increased expansion gives, roughly stated, a decreased steam consumption, about in the ratio of the square root of the pressure. This seems true in recent marine engineering; during the past ten years steam pressure has risen from 4½ to 6 atmospheres—50 to 75 pounds by gauge—and the consumption of fuel per hour and per horse-power has decreased from 2 to 1.8 pounds (0.9 to 0.8 kilograms). Incidentally the area of heating surface has decreased from 4½ to 4 square feet (0.4 to 0.37 square meter) per indicated horse power, that is to say remaining, as formerly, nearly 2 square feet per pound of coal burned per horse-power per hour (0.4 square inches per kilog.) where, as in some cases, pressures of 100 and 125 pounds are adopted (7 to 10 atmospheres, nearly), somewhat further gain may be expected.

Increased pressure has been accompanied by increased speed of piston—from 300 to 500 feet per minute (100 to 150 meters, nearly)—and both causes have combined to reduce greatly the size and weight of engines. Formerly 500

pounds (220 kilogs., nearly) per indicated horse-power was a common figure; to-day one-half that weight is often noted, and in special cases in which, as in torpedo boats, economy is not important, one-fifth, and even one-eighth those weights are said to have been reached.

Surface condensation is almost exclusively adopted, but the area of cooling surface is becoming less and less, and at the pressure soon likely to become general, the production of a vacuum may possibly cease to be desirable, as it is already known to be with unjacketed cylinders; and the non-condensing engine may yet displace the condensing engine at sea as it has on land, and on our western rivers where this comparison was earlier made, and where the evil effects of cylinder condensation were earlier perceived. A still for connecting exhaust and waste steam into feed water has already been used, and it must remain in use in all salt-water navigation.

Among the most interesting events of the years 1880–1881 have been the trials of the steam yachts "Anthracite" and "Leila." The first is a small vessel 86 feet long, 16 feet beam, and 9 feet draught ($27 \times 5 \times 2\frac{3}{4}$ meter, nearly), fitted with a three-cylinder compound engine, and carrying 300 pounds steam (20 atmospheres, nearly) and upward.

Trials in London show these engines to have required but 1.7 pounds of coal (0.8 kilog.) and 17.8 pounds (8 kilogs.) of steam per hour and per horse-power. Cylinder condensation amounted to 30 per cent. in the first cylinder, and of this nearly three-fourths was re evaporated before discharge from the third cylinder.

The same engines tested in this country require 21.6 pounds (10 kilogs. nearly) of steam per hour and per horse-power, the cylinder condensation becoming over 50 per cent., of which four-fifths was re-evaporated before reaching the condenser, the difference being probably due to a variation in the efficiency of the steam jackets and in speed of engines. This little yacht—the smallest that ever crossed the Atlantic—should be remembered in history, quite as much on account of the lessons in engineering learned on board the little craft as, on account of her far famous voyage.

The trial of the "Leila," under the orders of the U. S. Navy Department was even more instructive than that of the "Anthracite." The "Leila" is a Herreshoff yacht 100 feet long, 12 feet beam ($30 \times 3\frac{1}{2}$ in., nearly), and measuring 37 tons. With a "coil" boiler, steam at 120 pounds at the steam chest (9 atmospheres), and driving the boat 15 knots an hour (17 miles), the engines developed 150 horse-power, using but 16.4 pounds of steam (7.5 kilogs) per hour per horse-power. The cylinder condensation amounted to but 10 per cent.

An important deduction from the results of the trial of the "Anthracite" and the "Leila" is, that efficiency has little relation to size of engine when protection against cylinder condensation is secured, and this conclusion is further justified by the fact that some of the very best work has been done, where non-condensing engines have been compared, by small portable engines. Steam engines of five thousand horse-power are equaled in economy by engines of one-fiftieth that power. A large difference in magnitude seems more than compensated by a moderate difference in steam pressure. We may conclude that high steam pressure cannot be expected to give great economy unless employed intelligently. The highest pressure may prove least economical when the engineer neglects to provide against loss by cylinder condensation. In the cases of the "Anthracite" and "Leila," the higher pressure gave least efficiency. We may, perhaps, obtain some idea of the relative efficiencies that should have been attained in the following manner:

Assuming that the steam condensed and re-evaporated had one fourth the value of that remaining, the work done per unit of weight of working steam becomes for the two cases nearly as $\frac{70+7\frac{1}{2}}{70} = 1.11$ is to $\frac{90+2\frac{1}{2}}{90} = 1.03$, and as 16 pounds of steam per hour and per horse-power is to 15.9—practically the same, although the steam pressure was twice as great in the first case as in the second. We are evidently finding it more and more necessary to discover some means of making the interior surfaces of our steam cylinders of non-conducting material. That accomplished, the cost of power, in

quantity of steam used, will be reduced from ten to fifty and more per cent., according to the kind of engine considered. Until that is done, superheating, steam-jacketing, and high speeds of piston must be relied upon to give high efficiency; but only perfectly adiabatic expansion can give maximum economy of steam.

The error, long since detected by engineers experienced in the management and familiar with the working of steam engines, which has been fallen into by writers of authority, who have assumed that the condensation of steam due to transmutation of heat into work, discovered by Rankine and Clausius, produces the principal part of the water observed in the cylinders of engines working dry steam, is becoming generally recognized, and later writers are in a fair way to learn that it is not the fact that "the greater part of the liquid water which collects in unjacketed cylinders" "is produced by liquefaction of steam during its expansion;" but that this latter amount is insignificant, and that this water comes of cylinder condensation, sometimes with considerable leakage, and often amounts to a half or more of all the fluid supplied by the boiler. This fact once well understood, it may be hoped that this defect, existing in all heat engines, may soon be remedied to such an extent as no longer to constitute the great obstacle to further advance. The working of a fluid, of which the efficiency depends upon adiabatic change of volume, within a vessel so perfectly pervious to heat as is an iron steam cylinder, from the physicists stand point, involves an absurdity.

The trials of steam engines, now often conducted by the Forey & Donkin method of measuring the heat rejected, afford a reliable means of measuring actual efficiences. Recently, Eckart has applied the chronoscope of Hipp to the determination of the exact velocities of piston in mid-stroke, and we may expect soon to know much more than we do at present of the precise action of steam in the engine, and of causes of variation in efficiency.

Naval engineering is one of the most interesting and important branches of our profession, and the progress which has been made in its field during our generation illustrates the advances observed in nearly every other department. Naval works, whether in the civil or the military—in the "merchant" or the distinctively so-called "naval"—marine is to-day become almost purely the work of the mechanical engineer. The shipbuilder constructs his ships of iron and steel; their lines are laid down by the laws of engineering science; their parts are formed in the machine shop and put together by the same methods that are adopted in constructing their boilers. They are driven by steam engines designed and built by our fellow engineers, and the winds no longer either aid to any great degree, or seriously impede, their progress. Even their loading and the discharge of their cargo have become minor matters of engineering. The old-fashioned mariner is rapidly disappearing and the engineer is likely to become the responsible officer on the voyage as during construction.

Progress, if not more rapid in the Navy than in the Army, is more observable, and to me, at least, and perhaps partly because of my personal knowledge and closer relations, more interesting in its connection with engineering. A generation ago, the French "Napoleon" line of battle ship, with her 100 guns and 600 horse-power engines, represented the most formidable of naval vessels. A little later — 1856 — our "Wabash class" of screw frigates, with their fewer, but much heavier, guns, were thought the type of the coming fleet; but it was then that the modern ironclad came to revolutionize all naval warfare.

Those greatest of engineers, Robert L. Stevens and John Ericsson, and the greatest of naval architects, Edwin J. Reed, have led the way to the construction of the war ship of to-day—a craft carrying ordnance weighing from 25 to 160 tons, at speeds varying from 12 to 16 knots; plated with from 14 to 30 inches of armor, and yet penetrable by their own guns—a great fighting machine, designed, constructed and mainly operated by engineers. The daily advance noticeable in naval construction is a progress leading directly and rapidly toward bringing all naval warfare within the province of mechanical engineering. The fighting sailor of

earlier days is giving place to the fighting engineer and mechanic upon whom success in handling these great fighting machines must inevitably depend. To-day, if two professions are to be combined, it is easier for the engineer to learn and to practice the duties of the sailor than for the seaman to make himself at home among the cranks and shafts, the rods and the valves of the engineer. In our own navy, the line officer is becoming a skilled engine-driver, and the engineer is studying in all the higher departments of his profession, both in naval and steam engineering.

But a revolution is impending that will produce, as yet, unknown changes.

Ten years ago, I proposed a classification of naval vessels which was a little later again proposed by J. Scott Russell in a modified form. I stated that the increase so rapidly taking place in weight of ordnance and armor must sooner or later compel the division of all navies into three classes of ships, and an independent service of torpedo vessels: (1) a class of vessels for service in time of peace, of moderate size and speed, carrying a few heavy guns, unarmored and with great sail power; (2) a class of unarmored ships of very high speed under steam and carrying a light battery, such ships as might be best calculated to destroy the commerce of an enemy; and, (3) a class for heavy fighting, carrying the heaviest of guns and the most impenetrable of armor, with as high steam power as possible, and rendered, by division into compartments, as nearly unsinkable as possible. A few years later, I stated that "the introduction of the stationary, the floating and the automatic classes of torpedoes and of torpedo vessels has now become accomplished, and this element, which it was predicted by Bushnell and by Fulton, three quarters of a century ago, would at some future time become important in warfare, is now well recognized by all nations. How far it may modify future naval establishments cannot yet be confidently stated, but it seems sufficiently evident that the attack, by any navy, of stationary defences, is now quite a thing of the past. It may be looked upon as exceedingly probable that torpedo ships of very high speed will yet drive all heavily-armored vessels from the ocean, and complete the parallel between the man-in-armor of the middle ages and the armored man-of-war of our times." These words are fully justified to-day; and the non-success of naval vessels in later wars, and the production of such craft as the Polyphemus, making 17 knots, and as Ericsson's Destroyer, with its great submarine gun, and the self-propelling torpedo, guided from the shore, are simply very large straws, showing that the coming days of freedom on the high seas and of cessation of all naval warfare are not far away. This most splendid of revolutions is to be the work purely of the mechanical engineer. I have no doubt that many among my audience will live to see that forerunner of the millennium.

Gunnery is a branch of our profession which has been too much neglected by engineers; and progress, dependent upon laymen and upon a few of the military class, whose tastes rarely lead in the direction of construction, although, perhaps, much more rapid than should have been expected is much slower than may be anticipated, when this special department becomes the chosen field of educated, well-trained and talented mechanical engineers.

From the days of Tartaglia and of Rumford, the direction of movement has been readily traceable. Stronger and safer ordnance metal, breech loading in place of muzzle loading, increased velocity of projectile, a flatter trajectory with less lateral drift, and with enormously increased range are the features of changes now occurring. Whitworth's compressed steel, Krupp's breech mechanism and skillful design and construction have given us guns capable of driving shot at velocities of over 1,200 feet (over 360 meters) per second with small arms, and nearly 2,000 feet (600 meters) with heavy ordnance. Whitworth, with a comparatively small piece, has attained a range of nearly ten miles. The "machine guns" of Gardner, as built by Pratt and Whitney, and the Gatling and others, as constructed by the Colt Co. and the Ames Manufacturing Co., firing a thousand shots a minute, have rendered the old methods of warfare, in which large masses of troops were deployed in the open, entirely obsolete, while the accuracy of sharp-shooting at ranges of 1,000 yards or more make the use of any

unprotected ordnance at short ranges extremely difficult.

Hollow cast guns, as made by Rodman, although the best cast-iron ordnance ever known, are now of the past; and even the Armstrong, the Woolwich, and other guns built up in the forge, fail when made of 80 and 100 tons weight, as now demanded, and must inevitably, as I predicted several years ago, give place to solid steel guns of the Whitworth or other stronger type. Improved methods of making explosives and better adjustment to the work by variation of composition, and especially size and density of grain has enabled us to keep pressures much below 25 tons per square inch, while greatly increasing the energy developed per pound burned and correspondingly increasing the effectiveness of of ordnance.

The theoretical energy of good powder is about 250,000 or 300,000 foot pounds (80,000 to 90,000 kg. m. per kg., nearly) per pound. In experiments, every day in progress, we now get an actual result equal to two thirds.

This is is a branch of thermodynamics that must soon attract the attention of some scholarly engineer, familiar with practical work, and we may hope that so fruitful a field will not much longer be left so entirely uncultivated. There is, to-day, however, no difficulty in designing a gun to do any specified work, and but little in determining the resistance to be met and the energy demanded at a given range, or when attacking armor-plate. Fortunately, however, the days of iron-clads and of naval warfare will soon be numbered. Guns can be made to penetrate any thickness of armor that can be floated, and when the importance of a long bore, with slow burning or intermittently burned charges, becomes recognized, the effectiveness of ordnance against any armor will be such that the ironclad will soon vanish from the seas. There is still much to be done in perfecting ordnance, however, especially in its construction, and as yet our ordnance officers are completely at sea in respect to systems of construction of large guns. Treadwell and Woodbridge have pointed out one direction of progress by the application of the strongest known form of metal—hard drawn steel wire—in building up the barrel, and Whitworth has shown what wonders can be accomplished with steel in masses. Some of our fellow-engineers will undoubtedly go still further in this direction. The gun is already a heat engine of high efficiency, but thermodynamic investigations will show that this gas engine may be made still more efficient, and the chemist and the engineer will aid each other in perfecting it. A gun in which the charge expands 25 times should give to the shot an energy of 300,000 foot pounds per pound (90,000 kg. m., nearly) of good ordinary powder, and such a standard must sooner or later be closely approximated. As the heat is generated and expanded in a very small fraction of a second, the gas expands adiabatically, or insentropically, as Gibbs and Clausius would say, and the loss should be small except by incomplete expansion. It is sufficiently evident that we are yet to see the air chamber used intelligently, and, therefore, our guns lengthened greatly, and carefully proportioned to their work. It does not, even yet appear to have become understood that recoil is often simply an evil, and an avoidable one, with breech-loading guns; but the time must come, I think, when ordnance, whenever possible, if maximum battering power or range is required, will be held fast against recoil and thus the defect in efficiency, all the inconveniencies and some of the dangers now due to this waste of energy will be avoided. Recoil is, with modern ordnance, often an unmitigated and inexcusable evil. Increased accuracy and power with flattened trajectory and reduced drift will come with these improvements, and the last will give much greater convenience and safety in working, and will aid still more in the effort, which the engineer naturally makes, to unite guns and supporting structure as closely and firmly as possible.

That feature of recent progress in engineering which is to-day attracting most attention and awakening most interest in the minds of the public as well as of the profession, is the introduction of machine-made electricity, and of the electric light, but what seems to me the most important phase of this impending revolution is, I think, not yet generally comprehended. By the ingenuity and skill, the courage and the persistence, the energy and enterprize of our brother engineers,

Brush and Edison and their coadjutors, it seems certain that the dream of the great author of "The Coming Race" will in part be speedily realized, and that for the occasional mild light of the moon, or the yellow sickly flare of the gas flame, will soon be substituted the less uncertain and always available, and equally beautiful and mellow, radiance of the electric flame. This is but a beginning, however. A few months ago one of the most earnest and best workers of all who have been with me—at once, friends and pupils—made a very painstaking investigation of the efficiency of a powerful dynamo-electric machine kindly loaned him from Menlo Park. The mean of several series of tests gave, as a result, an efficiency of between 90 and 95 per cent. That is to say: Of all the power transmitted to the machine from the steam engine driving it, over 90 per cent appeared on the wire in the form of electrical energy. It follows at once that mechanical power may be transmitted through two such machines, again appearing as mechanical power, with a loss of less than 20 per cent. And it follows from this last fact that the distribution of power by electricity is not unlikely to prove a more important application of this wonderful force than is the electric light.

It is to this inestimably important advance in that field in which the mechanical engineer and the electrician have joined hands, that we owe the probable early success of the electrical railway, that promising scheme of simplifying the problem of transportation on our elevated railways; and it is not unlikely that the rising generation may see the completely successful introduction of this method of distributing power from a central source in our great cities, and even from that mighty reservoir, Niagara, with its 3,000,000 horse-power to far distant cities on either side of this great Continent. Sir William Thompson has stated it as probable that 25,000 horse-power may be sent by this method from Niagara to New York, Philadelphia, or Boston through a half-inch copper wire, losing twenty per cent. in transmission; he would effect distribution by using the Faure battery as an accumulator. The competition of this method of distributing light, heat, and power with the already practical plan of steam distribution introduced by Holly, of Lockport, and now coming into use in New York City under the direction of Emery, will be watched with unusual interest.

I have sometimes said that the world is waiting for the appearance of three great inventors, yet unknown, for whom it has in store honors and emoluments far exceeding all ever yet accorded to any one of their predecessors.

The first is the man who is to show how, by the consumption of coal, we may directly produce electricity and thus, perhaps, evade that now inevitable and enormous loss that comes of the utilization of energy in all heat engines driven by substances of variable volume. Our electrical engineers have this great step still to take, and are apparently not likely soon to gain the prize that will yet reward some genius yet to be born.

The second of these greatest of inventors is he who will teach us the source of the beautiful soft-beaming light of the firefly and the glow-worm, and will show us how to produce this singular illuminant, and to apply it with success practically and commercially. This wonderful light, free from heat and from consequent loss of energy, is nature's substitute for the crude and extravagantly wasteful lights of which we have, through so many years, been foolishly boasting. The dynamo-electrical engineer has nearly solved this problem. Let us hope that it may be soon fully solved, and by one of those among our own colleagues who are now so earnestly working in this field, and that we may all live to see him steal the glow-worm's light, and to see the approaching days of Vril predicted so long ago by Lord Lytton.

The third great genius is the man who is to fulfill Darwin's prophecy, closing the stanza:

> Soon shall thy arm, unconquered steam, afar
> Drag the slow barge or drive the rapid car,
> Or, on wide-waving wings expanded bear
> The flying chariot through the fields of air.

The quotation may excite a smile to-day, but when first published, just one hundred years ago, the last lines must have seemed hardly more extravagant than the first.

And it is to-day true that we are getting on, that even in the science of aeronautics progress, although slow, is still to be observed year by year, and

there is no department of engineering in which the art of the mechanic has opportunity for greater achievement. We have not yet learned to fly like Daedalus, and thus have escaped the fate of Icarus, but the flying automata of Archytas, and of Regiomontanus have been matched in our own times, and the navigation of the air is, very possibly, on the point of real advancement.

When it is considered that it is only 98 years, last June, since the Brothers Montgolfier invented the balloon inflated with hot air, and that two months later M. Charles made use of hydrogen for inflation, it will, I am sure, be admitted that the progress which I am about briefly to sketch is far from being discreditable. Since Chas. Green, the famous English aeronaut, just sixty years ago, substituted coal gas for hydrogen, the progress of ballooning has been rapid, and science is greatly indebted to Biot and Gay Lussac, to Flammarian, to De Foroville, and especially to Glaisher, among balloonists, although, as yet little direct advantage has come to mankind from their efforts. The practical application of the balloon has been confined almost exclusively to the purposes of military reconnoissance. During the Franco-German war the great French naval engineer, M. Dupuy de Lôme, succeeded in giving to the balloon a slow motion by means of a screw, and in directing its course by a rudder. His balloon was spindle or cigar-shaped, and contained 12,000 cubic feet of gas. It could carry 14 men, and the screw was worked by four or eight men. But while it could be moved slowly in calm weather, this machine gave no encouragement to hope that self-impelling balloons will ever become successful. To support the weight of machinery they must have great bulk, and with great bulk no machinery yet devised is light enough, yet strong enough, to drive them at any such speed as is necessary for navigation in even a moderate breeze. Our only hope lies in the direction of flying machines, lifted by their own power, not buoyed up by gas.

And this scheme cannot hastily be condemned, nor by any means at once decried as chimerical, although, to-day, there is but little accomplished by man in this direction. The carrier pigeon and the wild goose are but animated flying-machines, and it can hardly be pronounced impossible that man shall yet compete with them in their own element, as he has long since learned to excel the fishes in their element. And a little has actually been done. Men of science like Pettigrew, Marey, and De Lucy have studied the motions of the wings of birds and insects, have learned the laws of fluid resistance, and have paved the way to a real advance. The theory of propulsion has been long studied and in some directions well established. It has been shown that weight is probably not objectionable in aerial navigation, but actually a necessity; not weight but volume constitutes the impediment. A bird is a heavy but compact structure, of which the essential characteristic is that it incloses great power within small volume. De Lucy's measurements of various flying creatures show an irregular, but still unmistakable, general direction of variation of wing surface with size of animal. Comparing the lady-bird and the stag-beetle, the pigeon and the stork, the sparrow and the crane, we find the area of wing per unit of weight carried to be nearly as the cube root of their weights. Taking as a fair figure that obtained from the larger bird, I find that a man of the ordinary weight should be able to fly with wings having an area of only about 40 square feet (nearly 4 sq. m.). De Villeneauve states that a bat having the weight of a man would need wings only ten feet (3 meters nearly) long. Hastings makes the surface of each wing from 5 to 10 times $\frac{2}{3}\sqrt{W}$ where the area is measured in square centimeters and the weight in grammes. Marey has made birds in harness record graphically the motions of their own wings, and Haughton and Marey and others have determined the working power of muscles in proportion to weight and size, and the method of movement of muscles and wing.

Henson, Stringfellow, May and others have made self-impelling model flying-machines, some of which have actually lifted themselves in the air, and several of which have flown with great speed when once lifted clear of the ground. But the most remarkable achievement of all, perhaps, is that of Henson in making a steam engine, fragile to be sure, but still a working machine, producing a third

of a horse-power, and weighing *less than 15 pounds* (6½ kilogs). This machine was certainly more powerful than any bird of its weight could be. It is here that we seem most likely to be held in check, and it must be confessed that there is as yet but little on which to base an expectation of finding a satisfactory yet powerful motor.

Thus we are apparently approaching, though still, perhaps, far from, this goal, and we may barely venture to hope that the engineer who is to combine the elements of success, all of which are becoming determined, will in our own day win the fame that awaits the first successful builder of a flying-machine.

But all the efforts during this most wonderful of centuries just passing, of either men of science, or of engineers, would have been of little avail in the world, would have been unfruitful, however intelligent and however energetic the workers, without that other mighty power which preserves all science and sustains all art, which perpetuates both the fame of the inventor and the knowledge of his inventions. The art of printing, originating in an unknown past, dating its first grand expansion from the time of Guttenburg, and the use of moveable types, four centures ago, has seen its grandest development during this last half century.

The introduction of the power press and the gradual incorporation into one automatic machine of the web-perfecting press of Sir Rowland Hill and of Jephtha Wilkinson's, of Worms' cylindrical stereotype plates, of Richard Hoe's type-cylinder and double-acting fly-frame; of Applegarth's enlarged impression-cylinder, and of minor improvements have led to the creation of the modern press.

To-day a daily paper can be printed at the rate of 30,000 impressions an hour, each paper printed on both sides, cut from the great roll—hundreds of yards long—in which it came to the press, pasted in shape and folded exactly to size, and then counted off by the machine as delivered to the carrier. The work of the compositor is soon likely to be wonderfully accelerated by the type-setting machine, which has attained, to-day, most extraordinary perfection. Paige's machine receives a column of "dead matter" from the press, distributes it automatically, sets it up anew at the rate of 3,500 "ems" per hour, including setting, justifying, and distributing—five times the work of the unaided hand. Its type last longer than when set by hand, and every defective or turned type is thrown out by this mechanical automaton.

Of all the observable signs of progress that attract our attention in these stirring times none are more interesting, and none more vitally important, than those which indicate the progress of this nation and of the world in the means and the methods of preparing the coming generation for its work.

The accumulation of wealth depends upon our material progress, and constitutes the only means of securing a steady progression in civilization, of conferring upon the world the blessings of intellectual and moral advancement, and of comfort and healthful luxury. But the accumulation of wealth means, not the piling of gold and silver in treasury vaults, and not the aggregation of fictitious values in Wall street, but the production of real property in buildings, in enriched lands, in mill machinery, in means of transportation, and in every form of durable material essential to the creature comforts of mankind.

The accumulation of real property depends largely, if not almost entirely, upon two great social conditions—the cheapening of food and other destructible necessaries of human life by the introduction of labor-saving mechanisms and processes and the steady and skillful application of the intellect and of the manual skill thus set at liberty, to the production of that form of permanent wealth, the accumulation of which during the past century has given to the working-man of to-day comforts and luxuries unknown to kings and princes on the day of the birth of our country.

Now, all that can be done in this direction must be done principally by the mechanic and the engineer, and our immediate duty is to see to it that our children and our children's children shall have every opportunity to acquire that knowledge and that intellectual power, and to gain those means and powers of directing the forces of nature as well as to utilize their own natural strength and skill, and thus to do this work when the opportunity comes to them, with highest

success and most thorough efficiency. It is in providing the opportunity demanded by every good citizen to make his sons and his daughters capable of doing the work so coming to them, that the highest duties of the State remain to be fulfilled, and here it is that the signs of the times are most cheering.

When every man and woman, every boy and girl in the land is guaranteed the privilege of learning any business, and of engaging in any occupation that he or she chooses, or that circumstances may render advisable, and whenever and wherever it may seem best, a long step in advance will have been taken.

But the individual must be taught, not simply *permitted* to learn as best he can. Education, directed effectively with the object of giving, in least time and at least cost, a preparation for all the duties coming to the learner, whether in daily toil or in social life, is called for; trade schools must be incorporated into the common school system, and technical and professional colleges and great *Universities of Science and Art* must be placed beside the older academies of learning. And this need is most felt by our own colleagues, and by the people employed by them. He who would accomplish most in the profession of the mechanical engineer, or in the trades, must best combine scientific attainments—and especially experimental knowledge—with mechanical taste and ability, and with a good judgment ripened by large experience. He must be carefully, thoroughly and skillfully taught the principles of his art in the technical school, and the practice of his profession in office or workshop.

We have been late in seeing this necessity, and must suffer for our dullness as a nation; but we are beginning to open our eyes and to move in this most vital of all the duties of citizenship. One and two and three centuries ago, wise men like Pascal and Worcester and Vaucanson saw this greatest, highest duty of governments and citizenship, but it is only recently that we, as a people, have come to see its importance.

But now, the magnificent trade and technical school system of Germany, the older if less complete educational system of France, the tardily begun but splendid later work of Great Britain, and the grand beginnings made in the United States form a glorious commencement of a revolution that shall peacefully effect such changes during the next generation as, probably, no one can realize until after their actual accomplishment.

With trade schools in every town, techical schools in every city, colleges of science and the arts in every State, and with a great technical university as a center for the whole system, we shall yet see all combined in a social organization that shall insure to every one absolute freedom to learn and to labor in any department of industry, with absolute certainty of a fitting recompense for all the zeal, intelligence and good work that the worker, whether man or woman, may offer the world. Then, and then only, will the memory of those greatest benefactors of their race, Case and Hoe, Vasser and Durant, Rensselaer and Rose, Stevens and Packer, Pardee and Washburn be generally revered as we to-day revere them.

Then, and then only, will our profession attain its noblest development, and its science and its art, in closest union, aid most gloriously in the great work of emancipating mankind from the trammels of this animal nature, and of relieving the race from the pressure now felt in the terrible struggle for the necessities of life, substituting arms of iron and fingers of steel for these weak members of flesh to do the work of the world, leaving every human being having brains the opportunity to acquire knowledge, to enjoy life, liberty and the pursuit of happiness and to prepare for the future, as the knowledge, judgment and faith of the individual may dictate.

THE authorities of the Paris Mint propose to substitute for the present bronze piece, now almost as familiar in England as in France, a new coinage of a smaller and more elegant kind containing 20 per cent. of nickel. Specimen coins have been struck of the respective values of about a half penny (5 centimes), a penny, and twopence-halfpenny. The die used is the old one cut in the troublous time of 1793. Its device is an allegorical head of the Repuolic wearing a cap of liberty. It will be well for the Royal Mint to adopt a similar plan so far as the metal is concerned, for the bronze coinage of this country, as it is, is simply disgraceful.

THE DYNAMOMETER BALANCE.

Translated from "L'Electricien."

The exact measure of work has at present an important bearing upon the problem of the transmission of force to a distance by electricity. This operation is not without its difficulties, even when approximate results only are desired, and these are increased when the question applies to motors of feeble power or motors of high velocity, as is the case with dynamo-electric machines.

We sometimes require to know the total work absorbed by a machine generating a current, sometimes the available work produced by an electric motor. Here there are two quite distinct kinds of apparatus; those which measure the work expended are called "transmission dynamometers." The optical dynamometer of M. Latchinoff is of this class. (See Van Nostrand's Magazine for June last). Those which serve to measure the work produced belong to the same class as the Prony friction brake. It is well known that the method of this latter device consists in expending the work of the motor in producing friction, and then in measuring the value of the work of this friction.

M. Carpentier has improved the Prony brake in such a way as to apply it to the measure of the work of the little motors of M. Deprez. When the work to be measured is only a few kilogrammeters, it is always difficult to clamp the jaws of the brake with just the degree of force necessary to hold the lever arm in equilibrium, and all variations of the friction influence the results to an important extent. In order to obviate this inconvenience, M. Carpentier has devised an automatic clasp founded on the law governing the friction of a cord wrapped around a cylinder; a law according to which the friction increases much more rapidly than the arc of contact, and is practically illustrated in the belaying of a hawser to hold a ship.

The apparatus of M. Carpentier consists of two pulleys mounted upon the shaft of the motor to be tested. The first, A, is made fast to the shaft; the other, B, is a loose pulley.

Two cords are attached to B, which carry each a known weight at the extremity. The cord carrying the lesser weight, p, lies freely in the groove of the loose pulley. The other cord, also fastened to the loose pulley, is allowed to rest on the fast pulley, and sustains the weight P. Now, turning the machine in the direction in which the weight P acts, the cord which carries this weight produces friction on the running pulley A, and the difference of tension at the two extremities of the arc embraced by the cord increases very rapidly as this arc augments. The loose pulley tends to turn under the influence of the tension of this cord, but is restrained by the weight p acting on the other cord. The equilibrium is established automatically, and occurs at the instant when the tension of the cord carrying P (which varies with the arc over which it laps) is equal to the weight p.

If the pulleys have the same diameter the value of the work per second is given by the formula:

$$T=\frac{\pi dn}{60}(P-p);$$

in which

T is the work per second in the kilogrammeters;

d is the diameter of the pulleys in meters;

n the number of turns per minute;

P and p are the weights in kilogrammes.

Cords are conveniently used for motors of light power only. For heavier work M. Carpentier uses steel bands.

This plan is open to grave objections when applied to precise measurement. The frictional resistances, which are relatively large compared with the weights P and p being applied at the end of the shaft, tend to falsify the results to an extent inversely proportioned to the size of the motor, because the size of the arbors of small engines is relatively much greater than that of large ones. Furthermore, the weights P and p are not constant, by reason of the inverse wrapping of the

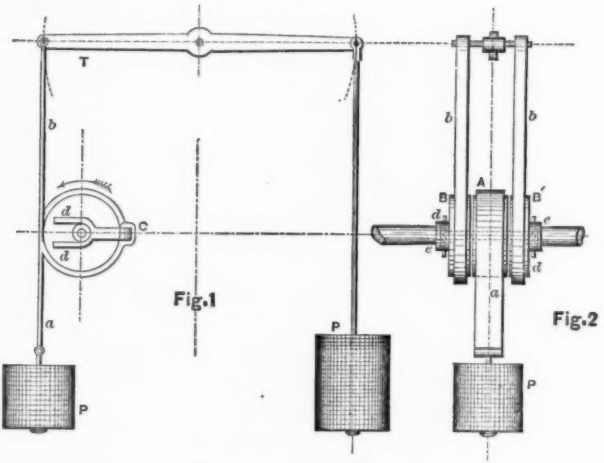
cords, but the error from this cause is of slight importance. The point of attachment of the cord that slides on the fixed pulley is not in the same plane as that of the loose pulley, which leads to an oblique pressure tending to unequal and rapid wear of the pulley and shaft, so that only narrow pulleys and bands can be employed.

In seeking to avoid these inconveniences, M. Raffard has constructed a dynamometric balance founded on the same principle as Carpentier's improved brake, but more useful practically, and capable of being applied to very feeble motors, or to engines of ten horse power, according to the size of the apparatus.

The lower side of the pulleys is allowed to dip into a shallow trough containing water or a solution of soap, for the purpose of lubricating the bands.

The size of the pulleys is regulated so as to present a circumference of a round number of centimeters, 20, 50, or 100. Knowing the value of $P-p$, and the number of revolutions per minute, the work is calculated by a simple multiplication.

The dynamometer balance is a complete apparatus; quite compact, and can be adapted in a few minutes to any machine by aid of a Cardan joint fixed to each end of the arbor of the brake.



M. Raffard's brake is shown in the figure. It consists of a pulley A keyed fast to a shaft, and two loose pulleys, B and B'. T is a lever to which the weights are suspended, C is a stirrup to which are attached the bands *a* and *b*. The weight of the stirrup is balanced by counterweights upon the arms *d*.

The principle of action is identical with that of Carpentier's brake. The weight P, acting by means of the lever upwards upon the pulley, relieves it of some of the pressure upon the bearings. There is no oblique action since the pressures act in the planes of the pulleys, and since the bands are not permanently fixed to the pulleys, the latter are not subjected to a constant wear upon one side only.

At the electrical exposition this brake is applied in the pavilion of the Societè la Force et la Lumière to measure the work produced by a Siemens machine driven by a Faure battery. Such measurements with a dynamometer so practical as Raffard's will serve to determine the true value of the so-called accumulators.

We shall also be able by the same means to determine the variation in efficiency of the dynamo-electric machines when the velocity and the current intensity are variable, for the real efficiency of these motors is nothing more than the relation between the electric energy furnished them and the effective work measured by the brake.

THE MANUFACTURE OF RUSSIAN SHEET IRON.

From "The Engineer."

So many different versons were current as to the process adopted for producing the sheet iron, known as Siberian, polished and unpolished, I determined when in the Ural to remain, if possible, at some one or more of the works, and watch the production from the ore to the finished sheets.

The manager, Ivan Ivanovitch Wohlsted, of the celebrated Demidoff works, obligingly offered me every facility, and in the report which follows the method followed there is explained; where from observation in other works, any difference of procedure of a serious nature was noted, I marked it, but the general conclusion I came to is that the manufacture of sheet iron is carried on with great care, great labor and expense, and that having good ore to commence with, the result is not difficult to obtain.

From the commencement to the end of the manufacture of the sheets I saw completed, I did not lose sight of the same, except they were under care; so that, as the manager said, there might be no uncertainty or quibble. The ore from which the metal is made is obtained close to the blast furnaces of the celebrated Tagil works, from which the C C N D bars are produced. This ore is very rich, and under arrangements is also used in other works, such as Takovleff, &c., the family of the original owner, Mr. Demidoff, of that district, having by marriage and sales given over right to others to mine there. The ore scarcely contains a trace of phosphorus, and not any trace of sulphur. The analysis is as follows:

$Si\ O^3$	7.871.
$Al^2\ O^3$	3.572.
$Fe^2\ O^3$	80.047.
Mn	—
$Mn^3\ O^4$	0.571.
Ca O	0.97.
S	—
Ph	0.25.

The flux used is ordinary limestone, found on the spot. Before being placed in the furnace the ore is roasted in heaps of from 10,000 to 15,000 tons, with charcoal made from *white* pine. If the iron is for sheets the workmen will not use charcoal made from *birch* wood. The roasting is done close at hand, quite in the open, and at any time of the year, the intense frost or heat not making any difference. In some works they prefer to roast the ore in the winter, and say *red* pine charcoal is not worse than white pine. The workmen assert that if charcoal made from birch wood is used, particularly in the blast furnace, then white specks are seen on the sheets. The managers say this is prejudice. The blast furnaces are oval. The size adopted as a standard has a capacity of 9000 cubic feet; the oval is 20 feet by 10 feet, being 52 feet high. The bottom is 3 feet diameter, and at 9 feet from bottom is full size of the oval. The system is Roshett's, with six tuyeres on each side, using hot blast at 200° Celsius. The furnace is charged every half hour with a thin layer of roasted ore and charcoal ore, broken up small and mixed with the flux; pieces of ore larger than a good sized walnut are not passed. The blast for three such furnaces is provided by three horizontal engines, each having a 29-inch steam cylinder and 5 feet stroke. The production is from 1500 lbs. to 2000 lbs. per day, 25 to 30 tons. New charcoal produces more than old, but the production varies little. The pig iron produced is at once puddled in an ordinary puddling furnace. The workmen attach importance to its being at once puddled, and make it into blooms of 100 lbs. to 200 lbs. weight. The puddling may be done with gas; it seems not to matter. Great care is taken to hammer the blooms well, to get rid of all impurities, under either a steam hammer or tilt hammer. Many workmen contend that the steam hammer is not so good as the tilt, but it seems simply prejudice. The blooms are at once reduced in a regular way into bars 5 inches wide, but of various thicknesses. After the bar has got rather cool the workmen stop rolling. These bars are at once cut into pieces 29½ inches and 30½ inches long, each

piece representing a future sheet, and being of various thicknesses for sheets of diverse weights.

Sheet iron in Russia is invariably made 4 feet 8 inches by 2 feet 4 inches (2 arshines long 1 arshine wide), and called 7 lbs., 8 lbs., 12 lbs., or 15 lbs. being made of all weights from 6 lbs. to 20 lbs. per sheet. Hence the thickness of the puddled bars is not much considered.

The puddled bars when broken show a fine granular fracture, somewhat steely, little if any fiber being found in the bars. About sixty of these pieces are taken—29½ inches for ordinary sheets and 30½ inches for polished or "glanced" sheets—and put into an ordinary furnace heated with wood from below, the bars being placed on ridges in the upper chamber, the flame impinging through three openings on either side. The rolling down of these bars into sheets is a matter of three processes. First, each slab is rolled out into a plate as near as possible—workmen being guided by the eye—2 feet 6 inches by 2 feet 8 inches. Six men are engaged in this process. One man screws down the rolls to a fixed standard of thickness. There are two rollers, one man draws the slabs, and the other carries to the rolls. Whilst these are rolling the slabs down a sorter selects them in lots of three, putting a smaller one between two larger ones, and they are thus in lots of three returned to the furnace. Secondly, these "threes" are not tied together in any way, but simply assorted. Again at a fair heat are drawn out and brought to the rolls, held open by the roller, and a boy throws between the plates prepared powdered charcoal; the bundles are then passed through the rolls, the rolls being screwed down to the same point as before, the thickness of the three being reduced to the same as each was previously. Now the sorter again divides the sheets into lots by thickness, and makes bundles—not tied bundles—of three of the thicker, four of medium, five of thinner, and returns them to the same furnace. Thirdly, when the bundle is again at a good heat—red cherry—these lots of plates are brought to the rolls, opened out, and charcoal again powdered all over them, and the lots are passed through the rolls, until the thickness of the lot is brought to the standard of the original one slab. The sheets are now all sheared to one length—5 feet; in the width they are not touched. The sheets are now ready for the finishing process. Before proceeding to this, let me describe the preparation of the charcoal, a matter to which the workmen attach much importance, but which the managers do not seem to consider of any moment.

The workmen object to birch-wood charcoal, and prefer yellow pine and large-sized charcoal. It is first carefully washed to get out all earthy matter, ground in a mortar mill, or pounded under a hammer, washed again and dried, again pounded and sifted through a fine sieve. The workmen attach the greatest importance to using charcoal; but I saw sheets prepared without—which seemed quite as good, but the workmen contend that the sheets without charcoal soon lose the "bloom," or fresh look, especially with unpolished sheets. The sheets from the third process are stacked to cool completely—the lots I had in hand were allowed to stand in a rack from evening to morning—and are then assorted, as near as possible by the eye, into sheets of equal weight; seventy or eighty being considered a "pair" or lot for the future processes. Each sheet, being examined and brushed, is then dipped into a tank of water—the tank is never cleaned out, but kept full—"older the water the better"—and kept at about blood heat. Taken out of the bath, each plate is powdered all over with the prepared charcoal, dusted from or through a coarse linen bag. If the powdering is not done "equally" the color of the sheets will not be equal. The sheets being thus prepared, on the top and bottom of the bundle are placed two or three old plates to protect the sheets. The bundles of sheets being placed in the furnace are very gradually heated—the workmen considering that the more smoke there is in the heating of the bundles the better the sheets will be; but to get the bundles to a bright red heat, not less than seven or eight hours should be employed. The bundles I had in hand were dipped, powdered and prepared by 3 o'clock, and were in the furnace till 10.20—the same furnace as before described, but that on and around the bundle, wood was placed to prevent direct action of

the flames and produce smoke. When the packet was removed from the furnace, at a bright red heat, it was laid on a large iron slab, and every sheet was turned over, brushed with a wet fir broom, and when the bundle had got to a dark red it was placed under a wrought iron tilt hammer, and received in four minutes 200 to 210 blows—the hammer weighing 45 poods (15 cwt.); after this hammering every sheet was again examined on both sides, any dirt specks removed; particular attention paid to there having been no welding.

The bundle was again made up as before, put back again into the furnace to be again re-heated—this took 50 minutes. It was then again examined; again put under the hammer at a dark red and hammered for 14 minutes, receiving 750 blows. This was repeated a third, fourth, fifth and sixth time in following sequence:

	Packed in furnace.	Under hammer.	Number of blows.
	hours min.	min.	
First as noted.	7 30	4	200
Second time...	0 50	14½	750
Third time....	0 30	15½	775
Fourth time...	0 24	11	550
Fifth time....	0 30	7	350
Sixth time....	0 30	7	350
Totals.....	8 34	59	2975

The bundle of sheets being examined by the hammerman, is handed over to the finishers, generally between 2500 and 3500 blows having been given. The first thing for the finisher to do is to examine each and every sheet. A ⅜-inch or ¼-inch plate is put on the slab, and each sheet examined; between each of the hot sheets is placed a sheet of finished iron—or two if the bundler thinks best—so that the packet becomes a bundle of from 200 to 220 sheets. It is at once taken without any reheating, and the bundle receives from sixty to eighty blows from a cast hammer on a cast-iron anvil; the latter must be accurate. Note cast iron, for in the first process wrought is preferred. Having received this hammering they are called "half finished," and then the whole contents of the bundle is placed on one side to cool. This we did by letting them remain in rack all night again. The processes above noted commenced at 3 A. M., and finished at 6 o'clock P. M.; the men—six—had done nothing but work at four bundles, *i. e.*, about 300 pieces of puddled bar. I kept my eyes particularly on two bundles, which now consisted of 150 sheets. Next morning at six these 150 sheets were cut to exact selling size, 56 inches by 28 inches, by hand shears, which they find to be cheaper than cutting by machine.

It will be remembered that in the last process the hot sheets were placed between cold ones; now the process was exactly reversed. Our 150 sheets were cold, a hot bundle of 150 sheets was brought, and two bundles made up, each of 75 old hot sheets and 75 new cold sheets, in process of manufacture, care being taken not to put in the hot sheets whilst any appearance of redness remained. These bundles were then taken again to the polishing hammer, and each received in four to five minutes 140 to 150 blows. The hammerman declared from observing the motion of the plates they were now ready; the bundles were opened and we found certainly fine polished sheets. The working tool sheets being removed, the new sheets were taken to the store and subjected to a thorough examination, near 30 per cent. being condemned as "brack." Taking 180 pieces of puddled bars the result was as follows: We got 160 sheets; out of these 160 we lost 12 in the first processes by holing, cracking, &c., and on reception in magazine 43 were thrown out as imperfect from cracks, spots, or blemish in polish. The remaining 115 sheets were divided into two categories: (1) where polish was good, *i. e.*, equal all over the sheet, 67; (2) where generally polish was good, but not entirely equal, 48. The rest were considered "brack," and sold at about £2 per ton cheaper, for makers of small articles, on the spot.

Conversing with the men, they say formerly they considered the polish was produced by the blow of the tilt hammer giving a gliding motion to the sheets; hence the name of "glance" iron. It was also held as an article of faith that after every reheating powdered charcoal must be used. This is not the case, for sheets quite as good are pro-

duced without; but the men are paid on the production, and hence the managers allow them their own way. I saw a bundle of sheets done without the charcoal and without the dipping, the results being exactly the same. The covering sheets were not much burnt, the heat of furnace being only moderate.

DAMP: ITS CAUSES, EFFECTS, PREVENTION AND CURE.

From "The Builder."

UNDER this title M. G. Philippe, a civil engineer officially employed by the municipality of Rouen, has contributed to *Les Travaux Publics* a series of valuable and interesting papers, of which we reproduce the principal points. The subject is of universal and individual interest, and of even greater importance in the climate of England than in that of France.

The *causes* of damp in buildings are —1, the presence of water in the atmosphere and the soil; 2, the porosity of building materials, which absorb it.

Its *effects* are only too well known, and may be classified as—1, disintegration of masonry, with injury to wall papers and other similarly-placed decorations; 2, decay of timber, and injury to wooden furniture; 3, development of saltpetre on walls, with injury to wall decorations; 4, injury to health of inhabitants.

The decay of timber used in building often carries with it an especial danger in France, because there chestnut wood is frequently employed for large beams; and as this wood decays first at the heart, while the outside remains sound, no superficial examination will give warning when an important piece of timber may be about to give way.

The development of saltpetre results from drying after damp. It is well known that this substance can be obtained from old building materials, and the white patches which it forms upon perfectly sound walls are familiar. During the siege of Paris, in 1870, the possibility of utilizing it for military purposes was taken into consideration, and a committee was appointed to investigate the amount obtainable in this way in case of necessity. It reported that the production of saltpetre in a building was in direct proportion to its age and uncleanliness. This conclusion appears very obvious, when we remember that saltpeter consists of potash, combined with nitric acid, and that nitric acid is azotate of ammonia. Kuhlmann, a distinguished chemist, proved by experiment that ammonia contained in a porous body is oxidized by contact with the air, and becomes azotate of ammonia. Fermenting vegetable and animal matter everywhere furnishes ammonia, building materials are the porous body required, and all clays contain potash; so that all the component parts of saltpeter are ready to hand, and as soon as the moisture which has held it in solution is evaporated by drier air the salt appears upon the surface. It is not necessary that ammonia should be present in any offensive form; rain will contain it, and fogs (especially town fogs) carry it in comparatively large quantities.

The prevention and cure of damp may be attempted by—(1.) employment of suitable materials for cellars, and other parts of buildings below or on the level of the soil; (2.) damp-courses to stop the upward progress of damp; (3.) preparations of different natures, either to protect the face of an exposed wall from the weather, or to prevent damp in the wall from affecting an apartment; (4.) precautions against infiltration.

The most thoroughly sanitary foundation for a building is concrete; and the author recommends covering the whole level of the future building with a layer 4 in. thick, composed of two-thirds broken flints well washed, and one-third mortar made of lime and gravel sand. He estimates such a layer would cost about 2½d. per square foot.

Well-puddled clay forms a good and inexpensive foundation, in districts where it is easily obtained. A layer 8 in. thick should be spread over the site of the building, and extended for about 16 in. outside the walls; and the external 16 in. should be carried up with the wall until the level of the soil is reached. Clay

cannot, however, be used to form a dry flooring for old buildings, as can be done with concrete.

Various methods have been proposed and employed for destroying that porosity of building materials, which is one of the chief causes of the mischief. M. Sebille, a civil engineer in Paris, has patented a process for injecting materials (especially brick) with gas refuse, which penetrates their substance, and renders them impermeable by water, at the same time increasing their weight, and giving them a brown color. A wall built with bricks thus prepared is absolutely dry, and their price is only increased by about 3s. 4d, per 1,000. Good results have been obtained by immersing the materials in solutions of soap and alum successively, and by applying these two preparations to the thoroughly-scraped surfaces of the walls of buildings already standing. The result of the chemical re-action which follows is to fill the pores of the brick or stone with a fatty substance, which opposes the passage of water. The immersion costs about 1d. per cubic foot of material.

The method preferred by M. Philippe is to plunge the material with the hand into a solution of silicate of potash for a time, merely long enough to allow all the air-bubbles to disengage themselves from its surface, and then lay it aside for forty-eight hours before using. The additional expense is extremely small, and the results (according to his experience) very satisfactory.

Many varieties of cement and other material are employed for mixing with mortar, in order to render it impermeable by water; of these the principal are Vassy or Gariel cement, Vicat (from Grenoble), Portland, and Peterspense cements, ground brick, Pozzolana (volcanic), wood ashes, calcined oyster-shells, etc. The greatest additional expense from using any of these is from 3d. to 7d. per cubic foot of masonry. A layer of such cement 1 in. thick, lining the walls of cellars, etc., is very useful, and costs on an average a little over 3d. per square foot. M. Philippe does not recommend French Portland cement, which is prepared chiefly at Boulogne, and which is much used in the North of France, as it very imperfectly excludes damp, and is easily penetrated by saltpeter. Of French cements he prefers the most expensive—that of Vassy. For application to damp walls, solutions of soap and alum, used one after the other, have already been mentioned. Another substance which has proved useful for the purpose is gas tar. The wall must be well scraped, heated in parts by means of a hand stove, and the tar applied with a brush as hot as possible. It then penetrates into the pores, and hardens in cooling, forming a crust which arrests the passage of damp and saltpeter. The cost is very trifling.

An important and interesting piece of work of this kind was performed about the year 1813, under the direction of MM. Darcet and Thénard; and as their methods have not been surpassed, we quote a portion of their own account, extracted by M. Philippe from vol. 32 of the "Annales de Chimie et de Physique":

In that year, "M. Gros undertook to paint the cupola of the church of Sainte Genevieve. The surface had been prepared like a canvass, with a layer of strong size, covered with white lead mixed in drying oil. M. Gros consulted us upon the durability of this composition, and we did not hesitate to declare that it was far from offering the desired security against damp. After consideration and experiment, we adopted the following method. All the previously applied preparation was entirely removed; portions of the interior of the cupola were then successively and highly heated by means of a large gilder's stove, and our preparation applied with a large pincers, at a temperature of about 212° Fahr. To facilitate its absorption, the wall was re-heated once or twice during the process. Successive coatings were applied until no more could be absorbed. When dry, a coating of white lead mixed in oil was superposed, upon which the painting was to be executed. The preparation used consisted of one part of wax and three parts of boiled oil, with one-tenth its weight of litharge. The heat employed must merely stop short of carbonizing the oil."

The same process was applied by its inventors to two damp underground rooms at the Sorbonne. The mixture was slightly different, consisting of one

part oil prepared with litharge, and two parts resin melted in the oil—an operation of some delicacy. The plaster was allowed to remain on the walls, and they were thoroughly dried with a gilder's furnace, which, by an ingenious arrangement, was made to move along the wall at a fixed distance from it, and at any height. When dry they were again heated for the application of the varnish, as in the preceding case. Five coatings were absorbed; the sixth was partially absorbed, and formed a smooth hard surface to the wall. The cost of the process is chiefly that of the labor; the value of the materials being about 1d. per square yard.

M. Philippe proceeds to make suggestions and give opinions on various points of detail, some of which we reproduce.

Parquets may be preserved by laying them upon bitumen. This invention was patented by M. Gourguechon, but his patent has expired. It has been successfully varied by laying down a well-smoothed bed of cement, then applying a thin layer of asphalte to a portion at a time, and laying down the parquet before the asphalte had cooled. The only difficulty with these methods is that they cannot be used with pieces of parquet much exceeding one yard in length. The frames by which the parquet is held should be fastened to rows of spaced bricks, and the intervals filled up with pebbles, cinders, or other dry and healthy material, avoiding sawdust, old plaster, and similar matters.

Ventilating Bricks on the Flagedé system may be made on the spot in a mill supplied by the inventor, at the rate of from 300 to 400, per day, of almost any materials that may be at hand—plaster, conglomerate, brick earth, even of *torchis* (clay mixed with straw and grass). They admit air to the interior of the walls, and thus keep them dry. Their size is double that of bricks, and their price comes to about £1 per 1,000.

The *Journet patent* for dry floors or areas consists in laying down a bed of cement about 2 in. thick, in which small pipes are laid at about 1 in. apart, and then covered with another 2 in. layer. When the cement begins to harden the pipes are drawn out by the end, leaving hollow tubes through which the air can circulate if proper openings are provided in the walls.

Silicate applied to the surface of buildings renders them almost impervious to the action of weather. It has been applied by M. Kuhlmann to the principal monuments in the town of Lille, and to the new buildings of the Louvre in Paris, with the additional good result of harmonizing their tone with that of the older portions. It costs about 10d. per square yard for three successive applications at twenty-four hours' interval. M. Mignot has invented a cheaper preparation, colored to suit the different kinds of stone. It is to be noted that silicates cannot be used upon walls where saltpeter has been or is likely to be developed.

Enduits have been invented in great variety by different makers. A very excellent one, called Glyco metallic liquid, is prepared by MM. Caron et Dupuis. It prevents all action of damp on cement and plaster, by neutralizing the alkaline salts which they contain, and can be painted on with perfect security. Old walls should be well cleaned before it is applied; new ones will require three coats, which will cost about 9d. per square yard. An excellent preparation of gutta-percha is supplied by the Maison Gaudri, in Paris, for the same purpose, and costs about the same price.

Windows are one of the principal avenues of damp into apartments. One cause of this is the bad quality of the stone often employed. It should be as hard as can be obtained; or it might be covered with zinc, or coated with a good cement. Small leaden gutters may be placed inside the windows, to catch and carry off the rain which penetrates. This plan is particularly recommended for the windows of kitchens and bath-rooms, where the steam condenses on the glass in considerable quantity.

For *slates*, M. Philippe recommends either the Fourgeau or Chevreau system of hooks in preference to the ordinary method of nailing—which makes a hole through which damp penetrates.

Drains from closets should be furnished with a ventilating pipe, carried up with the chimneys, or which may (as at the Hôpital St. Louis and the old Hôtel Dieu at Paris) open direct into the kitchen flue, thus being always secure of a strong upward draught. In this way all unpleasant smells are obviated.

STRENGTH AND DUCTILITY OF THE COPPER-TIN-ZINC ALLOYS.

By ROBERT H. THURSTON.

Presented to 13th Annual Convention of American Society of Civil Engineers.

II.

The following tables record the results of tests made at the Physical Laboratory of the Stevens Institute of Technology at Hoboken:

5. RECORD OF TESTS BY TENSION.

Copper..80%
Zinc.....20%

ALLOY OF COPPER AND ZINC.

Lab. No. 585B.

DIMENSIONS. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original section P	Fractured section. P′	Original section. T	Fractured section. T′	Actual.
4800	.....	.....	.....	.....	.....	.0018
5000	.....	.....	.....	.....	.....	.0037
5200	.....	.....	.....	.....	.....	.0075
5400	.....	.....	.....	.....	.....	.0132
5600	.....	.....	.....	.....	.....	.0205
6000	.....	.....	.....	.....	.....	.0385
220	.....	.....	.....	.....	.....	.0127
6400	.....	.....	.....	.....	.....	.0622
6800	.....	.....	.....	.....	.....	.0904
8000	.....	.....	.....	.....	.....	.1849
8800	.....	.....	.....	.....	.....	.2450
9600	.....	.....	.....	.....	.....	.2979
10400	.....	.....	.....	.....	.....	.3530
11200	.....	.....	.....	.....	.....	.4495
11600	.....	.....	.....	.....	.....	.4880
12000 (*a*)	.....	.....	.....	.....	.....	
16750 (*b*)	16750	33140	55599	33140	55599	

(*a*.) Micrometer slipped, further reading of no value.
(*b*.) Total elongation, measured after breaking 1.62″.

6. Record of Tests by Transverse Stress.

Copper.... 80%
Zinc..... 20%

ALLOY OF COPPER AND ZINC.

Lab. No. 585.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	.995	.985

Proof stresses.	Deflection.	Breaking load.		Modulus of elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2db_2}$	$E=\frac{Pl_3}{48\delta 1}$
10	.0043	.....	.....	
40	.0124	.....	.....	9030560
80	.0206	.....	.....	10708667
120	.0296	.....	.....	11349217
160	.0363	.....	.....	12339278
200	.0449	.....	.....	12469814
3	.0056			
240	.0544	.....	.....	12530618
280	.0693	.....	.....	11327350
320	.0980	.....	.....	9141138
360	.1659	.....	.....	6074807
400	.3288	.....	.....	3405686
3	.2445			
400	.3352			
420	.4414			
440	.5885			
460	.7520			
480	.9590			
500	1.1763	.....	.....	1189949
520	1.5463			
540	1.6163			
560	1.86			
580	2.22			
600	2.62			
620 (*a*)	3.27	620	21193	

(*a*). Bent down without breaking; bar removed.
Fracture, "Surface in character resembling No. 584, but less jagged." Color: brass yellow.

7. Record of Tests by Tension.

Copper.... 62.5%
Zinc..... 37.5%

ALLOY OF COPPER AND ZINC.
Lab. No. 609 A.

Dimensions. Original and Final.		Stresses.		Proof load per square inch area of		Breaking load per square inch.		Extension.
Length. L, L′	Diameter H, H′	Proof.	Ultimate.	Original section. P	Fractured section. P′	Original section. T	Fractured section. T′	Actual.
5″	.798	500	.....	.....	.....	.....	.....	.0003
.....	.....	1000	.....	.....	.....	.....	.....	.0007
.....	.....	1500	.....	.....	.....	.....	.....	.0010
.....	.....	2000	.....	.....	.....	.....	.....	.0016
.....	.....	3000	.....	.....	.....	.....	.....	.0024
.....	.....	4000	.....	.....	.....	.....	.....	.0037
.....	.....	5000	.....	.....	.....	.....	.....	.0053
.....	.....	6000	.....	.....	.....	.....	.....	.0066
.....	.....	100	.....	.....	.....	.....	.....	.0008
.....	.....	7000	.....	.....	.....	.....	.....	.0087
.....	.....	8000	.....	.....	.....	.....	.....	.0123
.....	.....	100	.....	.....	.....	.....	.....	.0047
.....	.....	9000	.....	.....	.....	.....	.....	.0185
.....	.....	10000	.....	.....	.....	.....	.....	.0447
.....	.....	100	.....	.....	.....	.....	.....	.0359
.....	.....	11000	.....	.....	.....	.....	.....	.0810
.....	.....	12000	.....	.....	.....	.....	.....	1290
.....	.....	100	.....	.....	.....	.....	.....	.1163
.....	.....	13000	.....	.....	.....	.....	.....	.1782
.....	.....	14000	.....	.....	.....	.....	.....	2375
.....	.....	100	.....	.....	.....	.....	.....	.2197
.....	.....	15000	.....	.....	.....	.....	.....	.3148
.....	.....	16000	.....	.....	.....	.....	.....	.3877
.....	.....	100	.....	.....	.....	.....	.....	.3650
.....	.....	16500	.....	.....	.....	.....	.....	.4334
.....	.....	17500(*a*)	.....	.....	.....	.....	.....	.....
.....	.670	24380(*b*)	24380	48760	68979	48760	68979	1.55″

(*a*). Micrometer slipped.
(*b*). Broke 2 inches from "C" end. Fracture; light brownish yellow, very compact, diagonal surfaces slightly polished. Several times during the test a dull sound was heard from the piece, and at the same instant the resistance decreased, in one instance to the extent of 1,300 pounds.

8. Record of Tests by Transverse Stress.

Copper....62.5%
Zinc.....37.5%

ALLOY OF COPPER AND ZINC.

Lab. No. 608.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	.970	.972

Proof stresses.	Deflection.	Breaking load.		Modulus of elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
10	.0044			
20	.0061			
40	.0078			15325081
80	.0167			14315643
120	.0244			14697004
160	.0327			14622094
200	.0417			14332809
3	.0040			
240	.0506			14174185
280	.0598			13992465
320	.0690			13859204
360	.0775			13881558
400	.0874			13677164
3	.0023			
440	.0958			13757029
480	.1028			13953576
520	.1102			14101299
560	.1198			13969106
600	.1318			13604210
3	.0048			
640	.1493			12810242
680	.1630			
720	.1832			11771840
760	.2130			
800	.2628			9097079
3	.0760			
840	.3160			
880	.4461			
920	.6000			4978218
960	.7782			
1000	.8927			3347588
3	.7277			
1040	1.1753			
1080	1.53			2109413
1120	1.88			
1160	2.23			
1200 (*a*)	3.13	1 200	43 216	1145709

(a) Bar bent down without breaking.

9. Record of Tests by Tension.

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper.... 58.22%
Tin..... 2.30%
Zinc..... 39.48%

TOBIN'S ALLOY.

Lab. No. 856B.

Dimensions. Original and final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Breaking load per square inch.		Extension.
Proof.	Ultimate.	Original section. T	Fractured section. T′	Actual.
150				.0
500				.0012
1000				.0022
1100				.0024
1200				.0026
1300				.0028
1400				.0030
1500				.0032
1600				.0034
1700				.0036
1800				.0038
1900				.0041
2000				.0044
2500				.0054
3000				.0064
3500				.0074
4000				.0081
4500				.0088
5000				.0095
150				.0022
5000				.0113
6000				.0125
7000				.0137
8000				.0150
9000				.0165
10000				.0176
11000				.0189
12000				.0202
13000				.0213
14000				.0226
15000				.0240
16000				.0254
17000				.0268
18000				.0282
19000				.0297
20000				.0313
150				.0150
5000				.0215
10000				.0279
15000				.0345
20000				.0399
21000				.0423
22000				.0447
23000				.0473
24000				.0494
25000				.0527
26000				.0568
27000				.0615
28000				.0674
29000				.0771
30000				.0873
31000				.0958
32000				.1277
33000				.1577
33800 (*a*)	33800	67600	73160	

(*a*) Broke. Fracture; yellowish gray, with light pinkish shade. Open granular structure, with a few very minute blow holes, several lustrous points scattered over the surface. No radiated lines were seen like those of the transverse fracture.

10. Record of Tests by Transverse Stress.

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper....58.22%
Tin..... 2.30%
Zinc.....39.48%

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	1.010	.993

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
3				
10	0.0024			
20	0.0046	.....	.....	11760504
40	0.0098	.....	.....	11040471
80	0.0202	.....	.....	11712635
120	0.296	.....	.....	10965874
160	0.418	.....	.....	10353743
200	0.0517	.....	.....	10643891
10	.0032			
3	.0011			
200	.0532			
240	.0612	.....	.....	10607511
280	.0712	.....	.....	10637306
320	.0802	.....	.....	10792679
360	.0908	.....	.....	10724336
400	.1000	.....	.....	10819661
10	.0027			
3	.0008			
400	.1010			
440	.1095	.....	.....	10869067
480	.1197	.....	.....	10846777
520	.1294	.....	.....	10869829
560	.1403	.....	.....	11578364
600	.1511	.....	.....	14321161
10	.0032			
3	.0015			
600	.1515			
640	.1629	.....	.....	10627046
680	.1740	.....	.....	10570934
720	.1846	.....	.....	10550048
760	.1944	.....	.....	10574771
800	.2038	.....	.....	10617922
10	.0043			
3	.0032			
800	.2028			
840	.2142	.....	.....	10607511
880	.2247	.....	.....	10593349
920	.2344	.....	.....	10616562
960	.2433	.....	.....	10672909
1000	.2550	.....	.....	10607511
10	.0064			
3	.0046			
1000	.2544			
1040	.2642	.....	.....	10647661
1080	.2764	.....	.....	10569132
1120	.2847	.....	.....	10641044
1160	.2951	.....	.....	10632674
1200	.3062	.....	.....	10610509
10	.0114			
3	.0093			
1194*	.3069			
1240	.3170			

* After 55 minutes resistance decreased from 1200 to 1194 pounds.

10. RECORD OF TESTS BY TRANSVERSE STRESS.—*Continued.*

Copper....58.22%
Tin..... 2.30%
Zinc.....39.48%

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between supports.	Breadth. b.	Depth. d.
22″	1.010	.993

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
1280	.3276			
1320	.3398			
1360	.3528			
1400	.3673	.....	.....	10310049
10	.0210			
3	.0193			
1400	.3695			
1440	.3817			
1480	.3959			
1520	.4102			
1560	.4236			
1600	.4395	.....	.....	9847245
10	.0407			
3	.0387			
1600	.4405			
1640	.4537			
1680	.4704			
1720	.4882			
1760	.5042			
1800	.5205	.....	.....	9354174
10	.0743			
3	.0727			
1800	.5230			
1840	.5383			
1880	.5586			
1920	.5823			
1960	.6076			
2000	.6343			
10	.1340			
3	.1326			
8(*a*)				
3	.1320			
2000	.6390	.....	.....	8955262
2040	.6594			
2080	.6856			
2120	.7140			
2160	.7456			
2200	.7777	.....	.....	7651812
2240	.8106			
2280	.8621			
2272(*b*)	.8621			
2268(*c*)	.8621			
2260(*d*)	.8621			
2256(*e*)	.8621			

(*a*) After 10 minutes resistance increased from 3 to 8 pounds.
(*b*) " 1 " " decreased " 2280 " 2272 "
(*c*) " 3 " " " " " " 2268 "
(*d*) " 25 " " " " " " 2260 "
(*e*) " 60 " " " " " " 2256 "

10. Record of Tests by Transverse Stress.—(*Continued.*)

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper.....58.23%
Tin 2.30%
Zinc.....39.48%

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between Supports.	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
2288 (*f*)	.8665 (*f*)			
2290	.8658			
2300	.8722			
2310	.8763			
2320 (*g*)	.8843 (*g*)			
2312 (*h*)	.8843			
2309 (*i*)	.8843			
2260 (*j*)	.8770 (*k*)			
2270	.8867			
2280	.8893			
2290	.8919			
2300	.8948			
2310	.8967			
2320	.8990			
2330	.9019			
2340	.9063			
2350	.9165			
2342 (*l*)	.9165			
2350	.9189			
2360	.9239			
2370	.9418			
2380	.9529			
2390	.9650			
2400	.9764			
2410	.9888			
2420	1.0048			
2430	1.0189			
2440	1.0333			
2450	1.0438			
2460	1.0553			
2470	1.0755			
2480	1.0865			
2490	1.1013			
2500	1.1265			
2510	1.1341			

(*f*) to (*g*) presents slight elevation of Elastic Limit.
(*h*) Resistance decreased in 3 minutes from 2320 to 2312 pounds.
(*i*) " " 10 " " " 23.0 "
(*j*) Resistance decreased in 66 hours 13 minutes from 2320 to 2260 pounds.
(*k*) Reading of extension apparatus changed, so as to correspond to deflection of 8770 -probably caused by gradual set of machine under the constant strain, and compression or bending of the lower transverse timber
(*l*) Resistance decreased in ten minutes from 2350 to 2342 pounds.

10. Record of Tests by Transverse Stress.—(*Continued.*)

TRIPLE ALLOY OF COPPER, TIN AND ZINC.

Copper.....58.22%
Tin..... 2.30%
Zinc.....39.48%

TOBIN'S ALLOY.

Lab. No. 856.

Dimensions.		
Distance between Supports.	Breadth. b.	Depth. d.
22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta I}$
2520	1.1475			
2530	1.1647			
2540	1.1818			
2550	1.1918			
2560	1.2073			
2570	1.2298			
2580	1.2445			
2590	1.2585			
2600	1.2851	.....	.....	54 72552
2610	1.3063			
2620	1.3288			
2630	1.3406			
2640	1.3556			
2650	1.3747			
2660	1.3973			
2670	1.4178			
2680	1.4447			
2690	1.4665			
2700	1.4898			
2720	1.5057			
2730	1.5303			
2740	1.5603			
2750	1.6106			
2760	1.6279			
2770	1.6395			
2780	1.6581			
2790	1.6899			
2800	1.7285	.....	.....	4331697
2810	1.7599			
2820	1.7793			
2830	1.8111			
2840	1.8553			
2850	1.8807			
2860	1.8936			
2870	1.9453			
2880	1.9881			
2890 (*m*)	.....	2880	95623	

(*m*) Broke in the middle in putting on strain. Gave warning by a slight crackling sound a few seconds before breaking, and broke gradually.

Fracture: Yellowish gray, with slight pinkish tinge, somewhat like brass alloy No. 612, but more yellow. Coarse granular structure, with radiated fibers near the edges. Slightly lustrous. Fractured section—trapezoidal.

11. Record of Tests by Transverse Stress.

		Dimensions.		
Copper.....55.00%	TRIPLE ALLOY OF COPPER	Distance between Supports.	Breadth. b.	Depth. d.
Tin 0.50%	TIN AND ZINC.			
Zinc.....44.50%	Lab. No. 1001.	22″	1.″	.979″

Proof Stresses.	Deflection.	Breaking Load.	
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$
3			
10	.0021		
20	.0051		
40	.0122		
80	.0417		
120	.0321		
160	.0417		
200	.0519		
10	.0024		
3	.0004		
200	.0520		
240	.0631		
280	.0734		
320	.0813		
360	.0899		
400	.1001		
10	0.0028		
3	.0008		
400	.0997		
440	.1102		
480	.1199		
520	.1300		
560	.1402		
600	.1516		
10	.0046		
3	.0018		
600	.1518		
640	.1623		
680	.1745		
720	.1881		
760	.2024		
800	.2164		
10	.0140		
3	.0119		
800	.2167		
840	.2296		
880	.2443		
1400			
3(*a*)	.3089		
10	.3097		
3	.3057		
.....	.....	2100	72308

(*a*.) No. 1001 (55 Cu. 0.5 Sn, 44.52 n.) The scale beam could not be raised by applying more pressure after 2,100 pounds was reached. This was due to the rapid bending of the bar, which, however, could not be broken until it was nicked with a saw on all sides. The casting was not very sound externally, and the corners were somewhat rounded, owing to the metal not having filled the mould completely. After 1,400 lbs. was reached and applied, a test was made to determine the recovery from set with time. When balanced at lbs. the micrometer read 0.3089″. After 20 minutes the scale beam balanced at 5½ lbs., and after 15 hrs. 45 minutes at 10 lbs. The reading of the micrometer was again taken, it being this time 0.3094″, showing a difference of .0005, which may be ascribed to the gradual recovery or springing back of the wooden frame of the machine after it was relieved from pressure. When the pressure of 5.5 lbs. was taken off and the scale beam again balanced at 3 lbs., a reading of 0.3057 was obtained, which indicates a recovery from set of 0.3094″—0.3057″=0.0037″ in 15¾ hours.

12. Record of Tests by Tension.

Copper, cast very hot. Cast Copper.

Lab. No. 581A.

Dimensions. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. P	Fractured Section. P′	Original Section. T	Fractured Section. T′	Actual.
400						.0004
600						.0007
1000						.0011
2000						.0022
3000						.0025
4000						.0027
5000						.0026
6000						0032
6800						.0083
7200						.0132
8000						.0358
8400						.0492
8800						.0642
9200						.0792
9600						.0942
9800						.1073
250						.0951
9800						.1082
10200						.1218
10600						.1408
11000						.1605
11400						.1794
11800						.2008
12200						.2191
12600						.2405
13000						.2626
14030						.3258
270						.3155
14000						.3270
14400						.3448
14600(*a*)	14600	29200	34790	29200	34790	.3760

(*a*.) Broke while reading was being taken. Broke ¼ inch from "A" end. The fractured section distorted from circular form. Three diameters measured .737″ .725″ and .732″. Fracture: fine, fibrous looking, radiated and compact. Strongest piece of copper yet tested.

13. Record of Tests by Transverse Stress.

Cast Copper.

Copper, cast very hot.

Lab. No. 581.

Dimensions.		
Distance between Supports.	Breadth. b.	Depth. d.
22″	.990	.980

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta I}$
10	0.0033			
40	.0116	.....	.....	9851369
80	.0224	.....	.....	10203205
120	.0355	.....	.....	9657120
160	.0513	.....	.....	8910400
200	.0729	.....	.....	7837853
5	.0260			
240	.0964	.....	.....	7112607
280	.1280			
320	.1705	.....	.....	5361919
360	.2253			
400	.3079	.....	.....	3711460
5	.2040			
440	.4169			
480	.5565			
520	.7540	.....	.....	1970274
560	.9155			
600	1.1635			
5	1.0085			
600	1.2105			
640	1.37			
680	1.63			
720	1.93	.....	.....	1065786
760	2.23			
800	2.60			
820	2.83			
840	3.09			
860(*a.*)	3.49	.....	.....	720375
1150(*b.*)	5.74			
3000(*c.*)	8.00	3000	29848	

(*a.*) The supports slipped. Placed the bar on cast iron fixed supports 20 inches apart, and (*b.*) 1 150 lbs. gave it a further deflection of 2¼ inches. Moved the supports to 10 inches, and applied (*c.*) 3 000 lbs., when bar broke, the total deflection being about 8 inches.

Fracture: Coarsely fibrous and radiate from center of surface of fracture. Color: Dark red from superficial oxidation. Fibers interrupted and covered over with minute ridges, with sharp lines of separation.

14. Record of Tests by Compression.

Copper, cast very hot. Cast Copper.

Lab. No. 581.

Dimensions. Original and Final.		Stresses.		Proof Load. Per Square Inch Area of Original Section. P	Breaking Load. Per Sq. Inch Original Section. T	Compression.
Length. L, L′	Diameter. H. H′	Proof.	Ultimate.			Actual.
2″	.625	500				.0026
		1000				.0046
		2000				.0079
		3000				.0109
		4000				.0143
		5000				.0177
		6000				.0212
		7000				.0263
		8000				.0347
		9000				.0513
		10000				.0801
		11000				.1187
		12000				.1619
		13000				.2053
		14000				.2508
		15000				.2942
		16000				.3373
		17000				.3373
		18000				.4722
		19000				.4688
		20000				.5100
		21000				.5594
		22000	22000	71709	71709	.6415

THE ACTUAL LATERAL PRESSURE OF EARTHWORK.

By BENJAMIN BAKER, M. Inst. C.E.

Proceedings of the Institution of Civil Engineers.

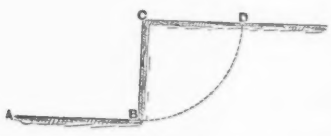
III.

DISCUSSION.

Mr. B. BAKER desired to add, that his object in bringing forward the paper was not so much to present certain facts for criticism as to induce others to give the results of their experience, and if every one helped a little he thought a very useful result would be attained.

Mr. W. AIRY said he had given considerable thought and attention to the subject of earthwork, and he considered the collection of examples in the paper would make it an extremely useful one for purposes of reference. The subject of earthwork was a very difficult one to deal with, and he wished to point out briefly in what this difficulty consisted. A B C D (Fig. 42) might be taken to be

Fig. 42



the section of some ground having a small vertical cliff at B C. There would be a tendency for the ground to break away and come down along some such line as D B. The whole problem of the stability of the ground, both as affecting the slope of the earth and the pressure against a retaining wall, depended upon the accurate determination of the line D B. It was not an exceedingly difficult matter to determine this line, if the constants of cohesion, friction, and weight of the ground were known; and he had himself dealt with the problem in a paper communicated to the Institution. The mechanical conditions of equilibrium were very simple; the force tending to bring the earth down was the weight of it; the forces tending to keep it from coming down were the friction along the line D B and the cohesion of the ground along that line. All those forces acted according to well-understood laws, and therefore if the constants of weight, cohesion, and friction of any particular ground were known, it was not difficult to find out the exact position of the line D B, and therefore the pressure on the retaining wall, or the shape of the slope. The question then arose, what was the real difficulty of constructing tables for practical use with regard to earthwork? Simply this, that the varieties of ground were infinite in number and very wide in range, and when that was the case it was quite idle to think of constructing tables for practical use. A man having a particular kind of earth to prescribe for, would not be able to ascertain by inspection what the constants of that earth were, and therefore he would not know whereabouts in a table to look; he would have to determine the constants for himself; and if he had to do that he had to do the whole work, and the tables were of no use to him. He thought the author had rather overlooked the enormous number of conditions of earth when he contrasted the small number of experiments upon earthwork with the large number of experiments made with timber. A piece of oak would give very nearly the same results for strength, elasticity, and so on, whether it was grown in Kent or in Yorkshire; and, therefore, when a few experiments had been made upon it, it was not necessary to repeat them over and over again. That was not the case with earthwork, because the conditions were so exceedingly variable. He exhibited a little rough machine he had used for testing earthwork and taking the cohesion of the ground. The block of wood might be taken to represent a block of raw clay taken out of a cutting. There was a common lever balance, and a couple of movable cheeks were fitted into chases cut in the sides of the clay block; and

the clay having been rammed in a box so that it could not move, weights were put in the scale until the head was torn off. After subtracting the weight of the piece that was torn off, and measuring the area of the cross section that was broken, the constant of cohesion was determined. For the constant of friction he arranged a certain number of blocks of the same clay in a tray, and scraped them off smooth; then he had another block of clay with a smooth surface which he put on it, and then tilted the tray until the loose block slid; that gave the coefficient of friction. He should like to refer to the exceedingly wide range of tenacity shown by different kinds of clay. In one set of experiments with ordinary brick loam, that clay gave a coefficient of cohesion of 168 lbs. per square foot, and a coefficient of friction of 1.15. With some shaley clay out of a cutting in the Midlands, he had found a coefficient of tenacity of 800 lbs. per square foot, and a coefficient of friction of 0.36. That was a very wide range, but it was only a part of what was actually to be found in practice.

Mr. L. F. VERNON-HARCOURT wished to say a few words on the subject, as the author had referred to two or three works with which he had been connected. The author had pointed out, from the experiments he had recorded, that the pressure upon the back of a retaining wall was a good deal less than it was theoretically supposed to be—about one-half—but as he allowed a factor of safety of 2, it apparently came to very much the same thing. With regard to walls on a rubble mound, the author remarked that the base was in many cases small. That, he thought, was owing to two causes; first, that with a rubble mound for a base there was no chance of sliding; and secondly, that in those cases there was a rubble filling behind, which he supposed was about as good a material for backing as could be got. The slope of the inner face of the rubble mound of the breakwater at Alderney harbor had been referred to as $1\frac{1}{4}$ to 1; but it ought to be remembered that in that case the materials used were very large blocks of stone, and therefore the slope would be naturally steeper than under more ordinary conditions. Reference had also been made in the paper to St. Katharine's breakwater, Jersey, as an example of a wall built with a very small base. The author took the whole of the height of that wall as the proper height; but it would be observed that the top of the wall had what used to be called a promenade along it, and therefore the whole of the filling did not apply to the entire height of the wall. The author stated that the base was 28 per cent. of the height of the wall, but leaving out the promenade it would be 35 per cent. Of course it would be something intermediate, as there would only be the small piece of filling under the promenade to be taken into account additional, instead of what would be the filling at the back if it was filled up entirely to the top level. The author had referred to the West India dock wall, and stated that several portions of it had come forward. That, however, was not quite the case. It was true that two portions of the south wall came forward —that two surfaces of clay at some little depth below the wall slid upon one another. Probably some seam of sand or silt was washed out by the water behind the wall from between two layers of clay, and in that way the two detached surfaces of clay were free to slide upon one another. He was quite certain of the exact position of the surfaces of rupture, because he saw the two surfaces of clay after the excavation was made for rebuilding the wall, and they were as smooth as glass. The remedy for that appeared to him to be very simple, and it was certainly successful in the case in point. The wall had failed, as the author had stated, not from any fault in the thickness or the weight, but simply owing to the sliding forward; and instead of adding any further weight to the wall, the foundations were carried down to a greater depth; but it only required 2 or 3 feet more in depth in the basin wall foundations that had to be executed afterwards under precisely similar conditions. That was quite sufficient to keep the wall in a perfect state of equilibrium without the least coming forward; and he should imagine that was decidedly better on the whole than adding to the weight of the wall. It appeared to him that practice was rather contrary to theory in giving too great a thickness to the top of the wall, and too small a

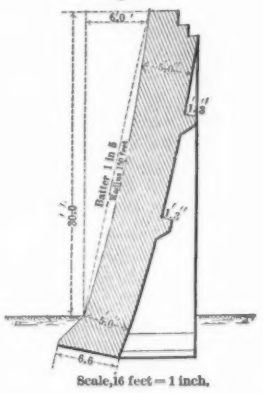
thickness, comparatively speaking, to the bottom; and that it would be better to have a wall more of the shape of the Sheerness wall a good deal lessened at the top, rather than a wall like those generally adopted, which had more par allel faces with a little additional thickness from the batter. He thought it would be better to make a wall narrower at the top and widening out more towards the bottom, and to bring the foundations of the wall well down into the ground so as to prevent any chance of sliding. In the case of the West India dock wall, besides the badness of the backing, there was a large amount of water that seemed to percolate from the Millwall docks, which were filled with water while the wall was being built, the docks not having been puddled. It was clearly shown that that had a considerable effect, because the north wall, though it was built in exactly the same manner, and though the water of the Export dock was really nearer, stood perfectly, as there was not the same amount of water pressure at the back, owing to the water being unable to penetrate through the silted-up bottom of the Export dock. He considered that the Institution was much indebted to the author for collecting and comparing so many valuable facts, as, whilst descriptions of particular works were very useful, it was by taking a general survey, from time to time, of the existing state of knowledge, in any special branch, that definite progress in engineering science was most likely to be promoted.

Mr. J. Wolfe Barry believed the statement was true, that the pressure against retaining walls did not approach to the theoretical thrust; at the same time he was of opinion that large retaining walls gave the engineer as much anxiety as any work he ever undertook. It should be remembered that, as a rule, the thrust which the walls had to bear came against them when the material of which they were composed was green, and unless contractors and others were very careful in strutting the new work, and allowing plenty of time for the material to set, there would be a condition of affairs in the early stages of the wall which would never arise after the materials were thoroughly consolidated. He wished to point out that it was for such reasons most engineers were now getting to realize the extreme desirability of using cement as much as possible. The early stages of engineering works were generally those in which the greatest risks were run, and if a slow-setting material were used, the strains would be exerted against it in its weakest condition, and disasters would occur such as would not happen at a later period. He agreed with the statement of the author with regard to the failure of retaining walls. No doubt, in ninety cases out of a hundred, the failure happened from bad foundations. The remedy in railway works was in many cases that shown in Fig. 17, which practically amounted to strutting the toe of the wall against the opposite wall, and so preventing it sliding forward. That was a very simple arrangement, and resembled in its effect the strutting of timber, which was generally carried out as a temporary measure by a contractor, when, an invert was going to be put in. If the engineer thought that a continuous invert could be dispensed with, a half measure, which was often perfectly good, was to adopt some of these struts—which, in fact, were a discontinuous invert, as shown in Fig. 17. In railway walls he thought engineers were a little too apt not to use struts above the trains, it being considered in many cases rather *infra dig.* to strut a wall. He could not see why it should be so. The horizontal strains exerted against the retaining wall about 14 feet or 15 feet high above its base were small; the struts consequently involved a very small expense, but they prevented all possibility of movement, and they saved a large amount in the cost of the wall. Having had something to do with the Metropolitan District railway, he could thoroughly corroborate the statement of the author, that the walls had stood remarkably well. As far as he knew, there was no sign of failure or incipient failure in any of them. There was, however, one little matter he had noticed, viz., that in many of the walls there was a small angular crack across the external angles of the piers. He did not know how the cracks had originated, but he thought they might be due to the action of frost; the corners getting saturated, the frost attacked the brickwork at the angles and broke them off. If so,

it rather pointed out that in such walls it might be desirable to round the angles, or have angular bricks and avoid the sharp corners.

Mr. W. B. Lewis said the experience gained in the construction of the Underground railway was so large that the profession naturally looked for the opinions of some of those who were concerned in it; and they all felt grateful for the fullness and ability with which those opinions had been expressed in the paper. He thought the paper was open to this reflection; that, whereas, the author in the earlier pages discredited the theoretical views that generally prevailed respecting retaining walls, in the latter part he stated that his practice had pretty well accorded with them. For instance, he gave the theoretical thickness for a retaining wall in ground that naturally stood at a slope of $1\frac{1}{2}$ to 1 as 31 per cent. of the height; and in the last paragraph but one he said his habit had been to make his walls $\frac{1}{3}$, or 33 per cent.; and in the Table with slopes from 1 to 1 to 4 to 1, which included all that engineers usually had to deal with, his theoretical thickness ran from 0.239 to 0.451, while in the concluding paragraphs of the paper he stated that the engineer must work between the limits of $\frac{1}{4}$ the thickness and $\frac{1}{2}$, which seemed to agree with the theoretical thickness. The general conclusion that engineers must work between $\frac{1}{4}$ and $\frac{1}{2}$ was different from the practice in which Mr. Lewis had been trained, and he had therefore brought a diagram (Fig. 43) of a retaining wall constructed according to Mr. Brunel's rules. Of course Mr. Brunel, who had to carry out very great works, modified his rules to suit the circumstances; but the diagram represented his standard section of wall such as was constructed at Lord Hill's land in the early days of the Great Western railway, and at the Britain Ferry docks two years before his death. It would be seen that the dimensions and peculiarities of that wall differed very much from those given in the paper. In the first place the wall had an average batter of 1 in 5, and at the top a batter of 1 in 10. Batter was a point on which Mr. Brunel always insisted, and Mr. Lewis was a little surprised that the author seemed to treat it with so much indifference. He was evidently aware of its value, because in the early part of the paper he mentioned a wall with a batter of 1 in 5, and a thickness of 1 foot, which he said was equivalent to a vertical wall of 1 foot 9 inches. Now anything that was equivalent to an increase of the original value of 73 per cent. was well worthy of consideration. Mr. Brunel's custom was to curve the face of the wall. The radius was 150 feet in the case of a 30-feet wall, or five times the height. The thickness was $\frac{1}{3}$ to $\frac{1}{6}$ the height. The counterforts were 2 feet 6 inches thick, and placed 10 feet apart from center to center, but were omitted in good clay cuttings. In the case of docks sometimes there was a difficulty, in consequence of the necessity of having the top more upright, and at Britain Ferry docks the radius was reduced by nearly one-half. Mr. Brunel, too, was in the habit of building behind what he called sailing courses, and the projections in Fig. 43 were 1 foot 3 inches. In the case of embankments the wall was supported by earth carefully punned against it and against the sailing courses, thereby adding considerably to the weight that had to be overturned when pressure came from behind. Then his rule for thickness was $\frac{1}{4}$, which was below the minimum given by the author. There were a number of such walls at Paddington, Bath, Plymouth, Briton Ferry, 30 feet high and 5 feet thick, and generally of nearly the same thickness at the top as at the bot-

Fig. 43



Scale, 16 feet = 1 inch.

tom. Another point Mr. Brunel was particular about was that the footings were made square to the batter, and when the ground was not good considerably larger footings were introduced. At Briton Ferry a 2-feet lining of concrete was employed at some places for watertightness. Concrete was not then in such general use as it was at present. Of course when exceptional ground was met with it was dealt with exceptionally. At a tunnel on the Wilts, Somerset, and Weymouth railway, some heavy ground had been found; the tunnel mouth was in a 60-feet cutting, a retaining wall 30 feet high was built, and the top was sloped back at ¾ to 1, with a 2-feet covering of masonry, and the wall was built precisely of the dimensions represented by Fig. 43; but as the ground was heavy, the batter, instead of being 1 in 5, was 1 in 4, and that was the only alteration. That wall was built in 1854, had never given any trouble, and was standing at the present moment. It seemed to him that Mr. Brunel, forty years ago, came nearer to the teaching of the experiments and of the reasoning in the paper, than the author had ventured to do in his own practice.

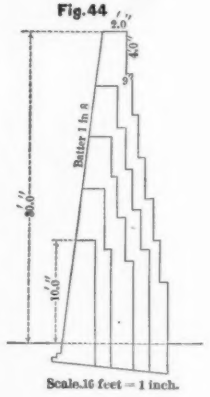
Mr. J. B. Redman observed that the author had undoubtedly filled a void in the literature of engineering; for, notwithstanding the great experience that most of the members of the Institution had of such catastrophes as those which had been referred to, it was only human like that they had not been often recorded by the designers of the works. Those who constituted what was now a select minority of the Institution would remember the partial failures of Mr. Robert Stephenson's retaining walls in the Euston cutting of what was then the London and Birmingham, and now the London and North-Western railway. Those partial failures were met by overhead horizontal girder struts supporting the walls, and it was rather curious that, notwithstanding all the experience that had been since gained, in a large number of instances, in metropolitan railways, the overhead girder had been, as it were, the natural sequence of what might be termed the unretaining wall. There was one circumstance which very much complicated the question of the direct lateral thrust of earthwork upon a retaining wall, and which rather curiously had not been mentioned by the author. It was incidentally referred to in the latter part of the paper, where the author said French engineers, in designing a wall at Marseilles, made the width of the base 58 per cent. of the vertical height, in consequence of the dip of the strata being towards the wall. In a large number of cases of the failures of retaining walls in open cuttings near London, he thought it would be found that the failure was entirely on one side. Where the dip of the strata was towards the cutting, and more especially if there were laminæ of clay, the superimposed strata often struck near the base of the wall; and a retaining wall on that side not only had to support the normal lateral thrust of the mass of earthwork immediately behind, but it had also a long wedge-like piece of earth impinging against the earth at the back of the wall, so that in many cases the thrust on the wall at the one side must be something like double the amount that it was on the other; because on the other side, the dip being away from the wall, the wall was subject only to the lateral thrust of the earthwork in its rear. The author had stated that the failures of many dock walls did not illustrate entirely the ordinary lateral thrust of earthwork; but Mr. Redman thought that such cases as the failure of the walls constructed by the late Mr. G. P. Bidder, Past-President Inst. C.E., at the Blackwall entrance to the Victoria docks, the partial failure of the same engineer's walls in the enlargement of the Surrey Docks, the similar catastrophe at the Victoria dock, Hull, in the work designed by the late Mr. John Hartley, and possibly also a similar movement in the South West India Dock wall, were all clearly attributable to lateral thrust. It might be said that the foundation was not taken down deep enough, and consequently the wall did not resist that thrust; but having had a somewhat extended and varied experience for a great number of years, he certainly was not prepared to indorse the dogma that a dock wall or a river wall must necessarily be so strong as to resist a head of water, or in width at the base equal to one-half the height. In the first place, the water ought not to be allowed to come behind the wall. There

were exceptional cases, perhaps, where that could hardly be avoided; but it seemed to him that laying down such a tenet was a premium for loose engineering, imperfect supervision, and lavish expenditure. He had himself, in the lower reaches of the Thames, erected some of the heaviest embankment walls on the river, where the thickness was only $\frac{1}{3}$ of the vertical height. It was true that the walls were founded on the best possible foundation—Thames ballast—and it was done as tide work; and the greatest possible care was also taken to keep the backing up to the same level as the wall, and indeed rather above the wall. In fact, the great mistake in retaining walls was the imperfect supervision exercised over the backing. If the backing were put in with tolerably fair material in thin horizontal layers and brought up in that way, the lateral thrust was reduced to a very small matter. The author had stated that the decayed timber wharves on the Thames and in other neighborhoods showed that the lateral thrust must be over-estimated; but it should be remarked that the skin might be stripped off the face of the earthwork, assuming that no water was coming against it, and it would stand, because from the length of time and consolidation of material, there was no lateral thrust. The example quoted of the breakwater at St. Katherine's, Jersey, appeared to be a case in point. He had nothing to do with the inception or execution of that work; but he thought the wall might be taken down and the heart of the pier would still stand. He would refer to two great Metropolitan failures which were well known, and which might be interesting in illustration of this subject. One was that of Greenwich Pier and the other of the Island Lead Works. The Greenwich Pier was constructed nearly half a century ago from the design of a local architect, Mr. Martyr. It was one of the heaviest embankments on the Thames; it had the greatest depth of water up to it, and it was, being in the hollow of the reach, subject to every condition of weather. The base was formed by cast-iron piling and cast-iron sheeting between, constituting a half-tide dam, and concrete was got in behind. Upon the top of the concrete there were large 6-inch York landings and a very solid, heavy brick wall. There were also outer piles, and the work was constructed in the best possible way. The case was somewhat complicated by the fact that a large amount of land-water came down and a large amount of spring water. There was a common sewer running through the heart of the work, and a large tidal reservoir for the Ship Hotel. The whole of that work, with the exception of the two returns and quoins and a small portion in front of the Ship Hotel, slipped into the river during the night some forty years back. The late Mr. Chadwick, who built the Hungerford suspension bridge, entered into a contract to restore the work on his own plan, acting as engineer and contractor, and he restored the portion that had failed with timber-bearing piles and a solidly-constructed brick wall. Shortly after the demise of Mr. Chadwick, the restored portion showed signs of failure, and Mr. Redman was called in by the Pier Directorate, and the matter resulted in a lawsuit, and a large sum of money was obtained in compensation. All he did was to bleed the pier by inserting a cast-iron pipe with a self-acting flap at the eastern end, and to remove and substitute with better material some part of the backing. He proposed driving land-tie piles at the back and some in front; but on consideration with the Directorate, it was thought that driving piles might be a ticklish operation. That was twenty years ago, and up to the present time the work had remained in the same state. It had settled somewhat at the eastern end, and there were reopened fissures in front, so that the movement had not altogether ceased. The wall of the Island Lead Works designed by the late Mr. R. Sibley, M. Inst. C.E., was the pioneer of cast-iron wharfing; and from the fact of the Limehouse cut having been deepened too close up to it, the wall failed. As the author had said, that case did not illustrate the absolute lateral pressure of earthwork, because this work, as long as it was not meddled with, stood satisfactorily. The leaseholders called in Mr. Redman on that occasion, and the freeholder consulted Mr. Bateman, Past-President Inst. C.E., and the late Mr. N. Beardmore, M. Inst. C.E., very wisely—to avoid a lawsuit—con-

structed a wall deeper down, to their satisfaction.

Mr. W. Atkinson agreed with Mr. Lewis's remarks with respect to the large amount of masonry or brickwork that the author had introduced in the cases of the metropolitan railways. He had been much struck with the proportion of $\frac{1}{8}$ of the height for the mean thickness of a wall; but looking at the diagrams, and taking into consideration what he had seen of the work, there was a very good explanation. It struck him that on the Metropolitan railway, where property was so valuable, the batter which the late Mr. Brunel introduced of 1 in 5 would be extremely inconvenient; either the roadway would have to be narrowed, or a great deal more property would have to be taken, than would be otherwise necessary. No doubt the author would be able to say whether that had any influence in the carrying out of the work. Then with regard to the general question of the walls and their failure due to bad foundations, it struck him that the two things should be entirely separate; that the foundation should be treated as a foundation, and that having been made sufficiently strong, a properly proportioned wall should be placed upon it. He rather gathered from the paper that the two points had been taken as a whole, and that the author meant, "I have a bad foundation, and I will make the whole to stand." If that were so, it would have been better policy to have made a foundation of concrete, and then put a wall sufficiently strong. With regard to the question of theoretical calculation, there was a French formula which agreed remarkably with what might be considered the ordinary practice. He himself had put up a good many walls, not perhaps as distinct retaining walls, but in connection with bridges on 48 miles of the Mid Wales railway, and he had found practically that the $\frac{1}{4\frac{1}{5}}$ of the height for the mean thickness stood perfectly well. In that case, it was to be borne in mind that there were two elements in addition to the theoretical calculation, namely, the projection of the footings where there was so much leverage, which was not taken into account in the calculation, and the weight of the earth resting on the projections or steppings at the back of the wall, Fig. 44. That, of course, aided the wall very materially; in fact, it might be called so much masonry saved. At all events, if merely the theoretical thickness of the wall was given, then, with the projections of the footings, and the weight of earth on the steppings, there was a very good margin of safety; and in that way the wall was erected with $\frac{1}{4\frac{1}{5}}$, or 33 per cent. less than the dimension advocated by the author, and

Fig. 44.



was a good and sufficient wall. One point with regard to walls was brought to his notice when in Canada, namely, the thickening of the top to resist frost. In ordinary circumstances the practice would be to put about 2 feet at the top, and then about 9 feet down a projection of 9 inches, and so on; but in Canada, on account of the penetration of the frost, it had been found necessary to make the top of the wall much thicker than was the practice in England.

Mr. H. Law desired to add his testimony to the great value of the facts laid before the Institution. It was upon such facts, the result of actual experience, that the most valuable data were formed. In the early part of the paper the author had pointed out that the formula usually adopted—Coulomb's—did not give the results which were obtained when loosely heaped materials were placed at the back of the wall; but a little consideration would show that that formula never was intended to apply to such cases. Coulomb's theorem distinctly took into account the adhesiveness or coherence of

the ground, and then determined, depending upon the line on which the ground separated, what the amount of pressure would be; and the value to the engineer was, that it determined what was the maximum which that pressure could be. Putting w=the weight of a cubic foot of the soil in lbs., h = the height of the wall in feet, r = the limiting angle of resistance of the soil, s = the angle between the line at which the soil separated and the horizontal, and P = the horizontal pressure in lbs. of the soil against the wall, then Coulomb's theorem might be thus expressed:

$$P=\frac{wh^2}{2}.\cot s.\tan(s-r).$$

Now in the case of a fluid, r, or the limiting angle of resistance, vanished, and consequently the result was that the co-tangent of s into the tangent of s became equal to unity, and

$$P=\frac{wh^2}{2}.$$

When the ground was sufficiently coherent to stand vertically, then the angle of separation being 90° the co-tangent of s became nothing, and the pressure became nothing. When the line of separation coincided with the limiting angle of resistance or r, that was to say, when there was a mass of earth sufficiently coherent not to break of itself, and lying upon a bed which happened to be at the limiting angle of resistance, the tendency of the earth to slide was exactly overcome by its friction, and r being equal to s, the tangent vanished, and P again became nothing. Now, between those two values there was a certain angle at which, if the ground separated, it would produce the maximum pressure, and that was given by Coulomb's theorem, which proved that when the line of separation bisected the angle made by the limiting angle of resistance with the vertical, then $\cot s=\tan(s-r)$, and

$$P=\frac{wh^2}{2}.\cot^2 s,$$

and the maximum pressure was obtained. The great value of the formula was to show, with a given weight of earth and a given limiting angle of resistance, what the maximum pressure was. It could not exceed the value expressed by making s half the angle between the limiting angle of resistance and the vertical. This formula could not be applied in the case of loose materials, as sand and gravel, because it was impossible for such materials to stand at any other than than their limiting angle of resistance; and under such circumstances there would be upon the wall only a comparatively small pressure, due to the unbalanced weight which remained from the efforts of the sand and the gravel to roll down upon itself. He wished to direct attention to one or two interesting exemplifications of excessive pressure which were met with in the works for the Thames tunnel. The Rotherhithe shaft, 50 feet in diameter, was built upon the surface and sunk by excavating beneath. That operation was successful until a depth of 40 feet was reached, and then, although the exterior surface had been made perfectly smooth by being rendered, it became earth-bound, and notwithstanding the earth was excavated to a depth of 2 feet round the whole margin, and 50,000 bricks were placed upon the top as a load, making the total weight 1,100 tons, and water was allowed to rise inside, the shaft refused to sink any farther. Now, taking the weight of the ground at 120 lbs. per cubic foot, which was about what it was on the average, and taking the coefficient of friction at 0.67, it would be found that a limiting angle of resistance of about 31° 15′, and a line of fracture of about 27° 30′, would show, by Coulomb's theorem, that the shaft would be bound, and therefore the practical result was quite in accordance with the pressure given by the formula. The author had mentioned a case of some heavy clay which had a pressure equivalent to a fluid pressure of 107 lbs., and if that clay was taken as having a limiting angle of resistance of about 5° or 1 in 10, and the weight was assumed to be 130 lbs. per cubic foot—which clay of that description might very well have—the formula would give 107 lbs. for the fluid pressure. He therefore thought these circumstances fully showed that where ground was coherent and adhesive, Coulomb's theorem applied. In the progress of the Thames tunnel there had been some remarkable cases of excessive pressure, where of course the weight of the water was superadded to that of the ground. He knew many instances of poling boards, 3 feet

in length, 6 inches wide, and 3 inches thick, supported by two poling screws bearing against cast-iron plates, being split lengthwise by the pressure of the earth against the outer surface.

Mr. E. A. Bernays said the inconsistencies alluded to in the paper tended to make it still more interesting than it otherwise would have been. There were few engineers who had carried out works, but were conscious of inconsistencies in their own practice and theories. The author had quoted M. Voisin Bey, the distinguished French engineer, as saying that he had rarely seen a long wall straight, and Mr. Bernays' experience fully confirmed that view. When it was straight the chances were there was a superabundance of material to keep it so. If it was run fine, as the calculations advised, the chances were 50 to 1 against having a straight wall. With regard to Mr. Brunel's section of wall, no doubt if it had a good foundation it was very strong for the material in it. It not only had a rising abutment to bring the pressure down upon the foundation, but it had counterforts, which added greatly to the strength of the wall, although of late they had gone out of fashion. He considered it was nearer 10 feet at the base than 5 feet, as, if the counterforts were 10 feet apart, the wall was, practically, a solid wall. If made of concrete instead of brickwork, it would probably be found better to make it solid at once. The batter added considerably to the strength, but it was not without practical disadvantages. The greater the batter the greater the disadvantage. The tendency of the batter was to throw the side of a vessel farther away from the wall than need be, and to entail cranes with longer jibs, as well as the use of much larger fenders. Iron ships were now all covered with anti-fouling composition, which might easily be scraped off. With all its disadvantages he would rather have a smaller batter for practical purposes when ships were to lie alongside the wall. He had seen a wall of this section in Woolwich Dockyard (built, he believed, by Sir John Rennie, Past-President Inst. C.E.), partially pulled down and refaced by the late Mr. James Walker, Past-President Inst. C.E., for the purpose of deepening the dock. It was about 30 feet deep, and was increased to about 38 feet by putting a thin wall in front of it. In pulling down such walls he had always found that the backing in settling hung upon the set off, and he had seen holes under the backing large enough for a man to creep in. He would not say that they were objectionable in other respects, but he preferred a battered back to a retaining wall to square sets off. The author had alluded to a wall that he was building, and had characterised it as "exceptionably heavy." But for that expression he would have been quite content to sit still: he hoped to be able to show that the exceptionable heaviness was justified by the exceptional circumstances under which it was being built. He did not think much of experiments with peas and pea-gravel, and bits of board a foot square when he had to deal with big walls. The author stated (p. 47) that "experience has shown that a wall $\frac{1}{4}$ of the height in thickness, and flattering 1 inch or 2 inches per foot on the face, possesses sufficient stability when the backing and foundation are both favorable." Unfortunately for dock engineers it rarely happened that either the foundation or the backing was favorable, and it was still rarer to find both favorable. This fact made the inconsistencies that really showed the thoughtful way in which the paper had been written. There was no attempt to square theory with practice; but the author had candidly pointed out where theory broke down in referring to the retaining walls of the Metropolitan Railway, and at the approach to the Euston Station, and in other instances. He agreed with the author that the Sheerness river wall had perhaps a greater moment of stability than any other wall in the world. The section assumed that the pile foundation would stand, though he doubted its stability; but if it would stand, half the thickness of the wall would have been ample. He did not know sufficient of the nature of the subsoil at Sheerness to be able to decide the point. He had been told that in many cases the piles were 40 feet long; and a few years ago, when a new caisson was put in the basin at the yard, there was great fear lest it would come forward when the water was let out. That was merely an instance of the cases where provision must be made for very different calculations from those

which were set out in any table. He quite agreed with the author that no calculations would meet cases where the work was exceptionally difficult. In most instances, engineers were called upon to make docks and other great works in the worst kinds of soils, such as estuaries, beds of rivers, or in deep alluvial deposits. The reason that he strengthened the wall at Chatham was because the original design showed symptoms of weakness, and several of the walls yielded about 10 or 12 inches. He did not say that that was entirely the fault of the walls, because the foundation was far from satisfactory, and there was a decided forward movement of the piles; but it was evident that the wall, for the greater part of the area, was not at any rate too strong for the work. When, however, he came to the east end of the works, where he had to build a wall 1,050 feet long without a single break, and with 35 feet depth of soft mud to excavate through, it was absolutely necessary to strengthen the wall, and it was decided to build it entirely of concrete, in order to be able to give the additional strength without additional cost. He was asked some years ago what angle this mud would assume at rest, and the answer he gave was that it would not lie flat. The basin at Chatham was being built in an old arm of the river Medway, and the basin generally stood in the middle of the river bed. On each side of it the mud was 35 feet deep on the average, and in some cases the distance to be filled in with backing was 500 feet. The whole of that backing had to be laid on this sliding mud, which brought pressure on the wall in a way far beyond anything he had ever seen allowed for in any calculation. If he understood correctly, Mr Giles had thought it necessary to provide, not only for the backing, but for a pressure of water nearly as high as the water in the dock. He did not agree with Mr. Redman that it was possible to get the walls built up so as to prevent water percolating. At Chatham there was a standing level of the water in the district, and wherever excavations were made to that depth water was found. The bottom of the basin was 20 or 25 feet below that level, and the water exerted a pressure just as if there was an ocean of that depth behind it. Then it was sometimes necessary to put heavy buildings, as at the Victoria Dock Extension, where large sheds loaded with heavy goods were placed from 100 to 150 feet from the wall. No one would say that such sheds would not exercise a great pressure on the adjacent wall. He would be happy to show the author the wall at the Chatham Dockyard Extension, and abide by that gentleman's judgment, whether "the exceptionally heavy wall" was not necessary to meet the peculiar conditions of the case.

Mr. A. Giles, after what Mr. Bernays had said about the pressure of mud behind dock walls, thought he was quite justified in adhering to the assertion he made many years ago, that a dock wall ought to be strong enough to carry a head of water behind it equal to its height. He cordially joined in thanking the author for the paper, but he considered it would have been better described as "On the Stability of Retaining Walls." The author had given many examples of dock and retaining walls, but after throwing over the theoretical calculation as to the pressure of earth against a wall, he said that in ninety-nine cases out of a hundred walls failed from faulty foundations, and not from want of strength in themselves. The various diagrams afforded rather congratulatory evidence of his own theory, that practically all the thick walls had stood, and most of the thin walls had given way. Referring to the old Southampton dock wall, mentioned as having been built 40 years ago, that had only a thickness of 32 per cent. at the base, but with the counterforts it was 35 per cent. That wall had been pushed forward, but it never came down; but it was saved by taking out the wet soil at the top and covering the top by a timber platform. Another wall which he had built had been referred to. That had a thickness of 45 per cent. at the base, and an average thickness of 41 per cent. Surely that wall ought to be strong enough to resist not only the pressure of water behind it, but even the pressure of mud that would not stand at a level. It had not stood without moving—not from any want of strength in the wall, but simply from the want of adhesion in the foundation. At Whitehaven the thickness of the wall was 37 per cent. at the base, and the mean thickness was 31

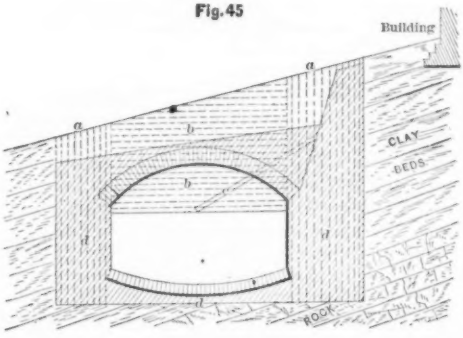
per cent., and it had stood. At Avonmouth these values were respectively 59 per cent. and 42 per cent. There was a very fine example at Carlingford of a wall with the base only 32 per cent. thick, and a mean thickness of 24 per cent.; but what could be said about a wall at Sheerness with a height of 40 feet and a base of 43 feet? It was stated that that wall had not moved, and Mr. Bernays had contended that it ought not to move; but he did not think any engineer of the present day would dare to design, or contemplate building, a wall of that character, because a wall of similar height in ordinary ground could be built for £60 a yard, while that wall would cost £300 a yard. In many instances it was not the inherent weakness of the walls that caused them to fall, but the slip at the bottom, and that was shown in Fig. 17 by the necessity which arose for thickening the wall so as to make the strength as 62 to 24. After all, the wall required still further strengthening by putting buttresses in front of it. The conviction he had arrived at was, that it was not generally the fault of the wall that caused the failure; but the fault of the foundation—not only that the foundation was not wide enough to give sufficient hold on the ground, but that there was not sufficient footing in front of the wall to enable the soil upon which the wall rested to sustain the weight. It was the same as if a cliff, 30 or 40 feet high, were put on tender soil. The soil would not be strong enough to bear it, and consequently the edge of the cliff would settle into the soil, the soil would burst up in front, and the pressure from behind would then make itself felt. He had seen that process take place in a wall which he had constructed, and it was only saved by putting buttresses in front of the footings. Something had been said in the paper about allowing a margin for contingencies. In that matter every engineer must decide for himself; but he thought that from $\frac{1}{4}$ to $\frac{1}{3}$ was rather a large margin, and he would suggest that the thickness of a retaining wall $\frac{1}{3}$ of the height would be, in nine cases out of ten, ample to resist the backward pressure; but he would insist upon having a large buttress in front of the foundation, carried down as deep as the lowest foundations of the wall. He was at a loss to imagine what the extraordinary projection in front of the wall at Marseilles (Fig. 25) meant. It might be that it was intended to hold the bottom down; and it was in that direction he would recommend retaining walls should be strengthened. A remark had been made about the necessity of having the upper part of dock walls nearly perpendicular, because of the friction of ships rubbing against them, and the inconvenience of ships lying at some distance from the quay at the coping level. That was perfectly true, and he believed it had been a common practice, in designing walls where there was a curved batter, to make the center of the curve level with the coping, by which a certain depth of almost perpendicular work was obtained from the coping level. He believed that was the correct principle; but he would urge particularly that, in making dock walls, the foundation should be much wider than they were in general, and that the bulk of the buttress should be in front of the face of the wall, and not behind. In all walls the excavation at the bottom should be carried down perpendicularly, with as little disturbance of the soil as possible; because in excavating the work, it was better to fill up the void so made, that there should be no tendency to slip after the wall was put in. There was another point which he thought was not sufficiently considered by engineers in designing dock walls. They were apt, when the excavation had been carried out, to think that they had got a good foundation; but he cordially agreed with the author when he used the word "lubricating." Notwithstanding what Mr. Redman had said, he did not think it was possible to keep water from getting behind a dock wall: he believed there was a point at which water would always be found: it would get up from the bottom or through the wall somewhere; and that being so, he thought that all the soil upon which the wall stood must be soddened and lubricated to a certain extent. He knew of instances where walls had stood for many years; but all at once the moment of lubrication had arrived, and they slipped in. He could only account for it by supposing that there was a tendency on the part of walls to get surrounded with water, by which they became of less specific gravity, or that the soil got satu-

rated, and therefore less able to bear the load put upon it. He would therefore urge upon all his professional brethren who had the conduct of dock works to look particularly to the front of the walls to ensure their stability.

Mr. W. R. Bousfield desired to make one or two remarks, from the theoretical standpoint which the author had deprecated. He referred to a point in which theory and practice would agree, viz., as to the effect of water behind a retaining wall. If there was an interstice of even an inch the effect on the wall would be exactly the same as if the whole ocean were behind it; therefore, a dock wall should be made to withstand a pressure equal to the hydrostatic pressure due to a head of water of the height of the wall. He wished to ask if the author could explain, somewhat more at length, the effect of lateral pressure in General Burgoyne's experiments, for he did not think the remarks were quite sound. If the lateral pressure of the ground, consisting, say, of loose rubble, was greater than the hydrostatic pressure, the fact of water being admitted would not make the slightest difference, because the water pressed equally on the earth and on the wall in opposite directions, so that the earth would be kept back by the pressure, and the difference between the lateral pressure and the hydrostatic pressure would be exerted by the earth on the wall. The only effect would be in the distribution of the pressure, which instead of being taken by the points of stone alone, would be distributed by the water over the whole wall. If the lateral pressure of the soil was less than the hydrostatic pressure, then of course, if water was admitted behind, it would exert upon the soil a force greater than the pressure of the soil on the wall; therefore, supposing the soil were rigid, the lateral pressure of the soil would be kept entirely off the wall. Of course, in practice, there were many points at which the pressure was excessive, so that, on the whole, the maximum pressure to be provided for would generally be rather more than the hydrostatic pressure.

Mr. E. Benedict described a retaining wall (Fig. 45) lately put up at Ryde. The ground was sidelong and at the foot of a clay hill, the strata dipping towards the work, and with a heavy building close to it. By cutting a trench and filling it as soon as possible with solid concrete in Portland cement carried up to the surface, the clay, which weathered rapidly when exposed to the air, was covered without delay, the concrete became agglomerated with the clay at the back, and did not allow any percolation of water. The excavation in front of the wall then proceeded without any movement of the ground occurring, and he thought that none would take place. Eventually a covered way was formed on the lower side of the wall, the arch of which was designed so as to form a continuous lying buttress.

Fig. 45



Mr. B. Baker, in reply, observed that he agreed, to some extent, with almost everything that had been said in the discussion, and he considered that the criticism had been very fair. He was glad indeed that he had elicited so many valu-

able opinions on the subject. Mr. Airy spoke about the difference in the cohesion of different clays. He had noticed the same thing himself, not merely in different clays but in the same clay. A railway cutting often refused to stand at a less slope than 4 to 1, and yet the same clay, after being tempered a little, might be found in an adjoining brick kiln standing with a vertical face. He had nothing to say with regard to Mr. Vernon Harcourt's comments, except that he agreed with almost everything that gentleman had said. Mr. Barry had made some sensible remarks about the advantage of using struts to retaining walls, and he thought it would be a good thing, in many cases, to imitate the old architects of cathedrals, and substitute flying buttresses for a heavy mass of materials. Some time ago he designed some very cheap sheds upon that principle, in which the roofs were light concrete arches supported by flying buttresses. Mr. Barry had referred to the cracks at the angles of some of the piers of the Metropolitan District railway retaining walls. He was satisfied that these did not arise from pressure, but from chemical action, because they occurred only in the case of certain bricks, and he knew where the bricks came from, and had every reason to mistrust them. He had sometimes found scaling occur all over the face of a wall, though of course the angle was always the weakest point, and nature always tried to round off an angle, as might be seen in Cleopatra's Needle, where there was no square angle. Mr. Lewis had described a wall designed by the late Mr. Brunel, but he did not approve of it, for reasons that had been set forth by Mr. Bernays. He himself had found exactly the same thing, namely, that in pulling down work where there had been the slightest settlement, the earth at the back did not rest on the offsets, indeed, not infrequently, a man could push in his arm between the offset and the filling. It was therefore idle to maintain, as Professor Rankine and others did, that the earthwork resting on the offset was as good as so much masonry. There was no economy in putting in the offsets, and he attributed the stability of apparently light walls so constructed to the pressure of the counterforts and the good quality of the backing. Mr. Redman had directed attention to the fact that there was an increased thrust when the ground at the back was sloping. No doubt that was so; and a case of that sort was referred to in the discussion on Mr. Constable's paper at the American Society of Engineers, where the ground at the back was sloping rock. When the wall was first put up and the backing was filled in, the whole mass came forward in consequence of the wedge of earth sliding down the surface of the rock. The masonry was pulled down, the rock cut in steps, and the wall rebuilt of the same thickness. Pig iron to the extent of 55 tons to the lineal foot was then placed behind the wall, and it stood perfectly well, though the thickness was less than 30 per cent. of the height. That was sufficient evidence of the importance of stepping the ground at the back. Mr. Atkinson said he thought it would be better to make the foundation satifactory first and then to build a thin wall on the top of it. At page 43 of the paper that point was alluded to and the answer given. Mr Law had submitted a formula, and drawn deductions from it, which he could not follow; but it seemed to him that the contention was that a loose material exerted less thrust on the wall than a more compact material, and that Coulomb's theory was not applicable to loose soil. He did not agree with that view in theory, and Lieutenant Hope's experiments showed that that was not so in practice, at least on a small scale. Lieutenant Hope placed a board behind the pressure board at such an angle as to include Coulomb's wedge of maximum thrust between the two boards, and found that the lateral pressure was quite as much when the board was at the slope of repose, $1\frac{1}{2}$ to 1, as when it was at half the angle. There was hardly any difference whether the board was horizontal or at a slope of $\frac{1}{2}$ to 1, or at any intermediate slope. Then it had been remarked with regard to one of his examples, in which the stability of the wall was equal to the fluid pressure of 107 lbs. per cubic foot, that theory would indicate the pressure to be about that amount; but a statement in the paper did not seem to have been noticed, that the wall never had that pressure on it, but failed by sliding forward. Of course it might have slid

forward with a pressure of 40 lbs. per cubic foot, but since the struts had been put in, there was not the slightest indication of movement, and therefore the moment of stability could not have been deficient. Mr. Bernays seemed to imagine that the expression "excessively heavy" reflected on the design of the Chatham dock wall, but the intention was the reverse. He entirely approved of it, and considered that it was a well-designed and creditable engineering work in every respect. It was one that he should imitate. His contention throughout the paper was that formulæ did not apply to such works, and although he began the paper with a diagram he set it up merely in order to knock it over. Mr. Giles considered that instead of the limits of $\frac{1}{4}$ to $\frac{1}{2}$ of the height for the thickness of a retaining wall, $\frac{1}{3}$ should be the limit with a buttress in front of the toe; but he did not think that that was the practice which had been followed in the Southampton Dock Extension, where the limit, he believed, was nearer $\frac{1}{2}$ than $\frac{1}{3}$—45 per cent. The curious slope projection in Fig. 25 was really an apron to protect the foundation, which was of clay. The clay was very hard when laid bare, and a sort of shield was put there to prevent its softening. He believed the same thing had been recommended by a committee of engineers in the case of the Belfast dock, where the wall failed; but it was applied too late, or the conditions were different, because the wall came forward notwithstanding.

ON THE REVELATIONS OF SANITARY SCIENCE.

From "The Builder."

This was the title of the paper read by Mr. Edward C. Robins, at Eastbourne, last week, on the occasion of the Sanitary Exhibition there already referred to. After alluding to the various papers recently read, and the discussions of the subject which have taken place with hopeful results, Mr. Robins made some useful general observations on the importance of sanitary knowledge, and on the advantages which had already become apparent from the spread of it, and thus proceeded:

Let us now briefly refer to some of the more important principles which sanitary science teaches, premising that there are two distinct systems of sewer-construction, broadly distinguished by the phrases *sewers of deposit* and *sewers of suspension*, both having reference to the water carriage of excrementitious matter. The *former* is adopted in many great towns, and does not necessarily provide for the immediate removal of the soil from the houses except in times of storm or very wet weather. At other times a system of flushing more or less intermittent is involved, owing to the absence of sufficient water for the carriage of the soil accumulations and refuse. The *latter* is adopted in some provincial towns, as Croydon, and requires the removal of the soil at once at all times of the year, or at least before the solid matters in suspension have had time to enter into that putrid state when sewage gases of a most deleterious character are generated within the sewer. Obviously the *former* system is one which, by providing for occasional storm-waters or heavy rains, over a large surface of land, as well as the ordinary house-sewage, necessitates the construction of vast cavernous sewers, which in dry weather (from the absence of adequate rainfall and sufficient flushing arrangements) constitute sewers of deposit, the emanations from which are often so deadly (owing to the insufficiency of ventilation) that disease and death are pent up within them, ready to find a way through every aperture into the dwellings of the rich and poor alike, so that the lives of the prince and the peasant are equally endangered by living in houses or hovels, whose drains are in direct communication with the public sewer, unless those precautions are taken which it is the business of sanitary science to discover and to enforce. The *latter* system is one which provides a sep-

arate sewer for storm-waters, or leaves them to care themselves and find their own way into the rivers and the sea, and thus necessitates the conduct of the house-drainage only in comparatively small pipes, the smallness of the bore concentrating the stream of water which carries with it the soil held in suspension along the narrow channel provided.

Mr. Chadwick, in his recent pamphlet entitled "Circulation or Stagnation," quotes the address of Mr. F. O. Ward, at the Brussels Congress in 1856, on a system of sewerage involving the utilization of the sewage by irrigation, briefly summarised in the following description of a sanitary Arcadia:

"The water which falls on the hills in a state of purity undergoes a natural process of filtration through sand, enters the rural collecting pipes, and passing through the aqueduct to the metropolitan distributing-pipes, finds its way to every story of every house in the town; when, again, after having supplied the wants of the inhabitants, it runs off enriched with fertilizing matter, which it carries away before allowing it time to ferment. This manure, driven along irrigation pipes, is deposited in the soil, leaving the water to pass into the drainage pipes, and flow on to the rivers. The rivers conduct it to the ocean, whence it rises as vapor under the heat of the sun, to re-descend as rain on the hills, enters again the collection-pipes, and recommences its vast and useful course of circulation."

In opening the discussion which followed the reading of my paper at the Royal Institute of British Architects, from which I have made the foregoing extracts, Dr. Corfield remarked: "Mr. Robins has said that civil architecture can never be divorced from the experience of sanitary science. I would go farther than that, and would say, that if it were not for the experiments that have been made by scientific men, no alteration in principle would be carried out, not only in architecture, but in everything else. If it had not been for the chemist Pasteur, for instance, all the vine-growers in the world would never have discovered the cause of the destruction of their vines; the fowl-keepers would never have discovered the reason for the loss of hundreds of thousands of their poultry by hicken-cholera; and the prevention of the silk-worm disease would have remained an unknown problem. And," he asked, "what is it that has caused us to think so much of *sewer-air*? There is one reason, and only one, and that is, that it has been shown by scientific experiment—by the experiments of sanitary science—that enteric or typhoid fever is produced by a constituent of that air; yet the public mind was not aroused to the necessity of preventive measures until one or two members of the Royal family suffered from that disease."

Sanitary science has revealed to us, by the positive experiments of its professors, the necessity of devising means for the ventilation or disconnection of the house-drains from the main town sewers, be cause it has been shown that foul gases will pass through water, that on one side of the water in a trap they are absorbed, and on the other side they are given out, and that this process goes on continually. And if this is the case, even when a house-drain is siphoned off by a water-trap, what must be the condition of those house-drains which are not trapped at all, but the sewer-air is laid on by those to the interior of the dwelling through any untrapped sink or closet, or leaky joint, and with the use of disinfectants serves only to conceal from observation, and to hinder the perception of the cause?

Dr. Frankland's experiments have proved that when water contains foul matter decomposition takes place in the water, and the surrounding air is contaminated by the bubbles of gas generated, releasing the infectious particles along with it, thus showing the desirability of intercepting manholes to house-drains, even where water-traps exist, and demonstrating the fatal consequences likely to ensue when neither water-traps nor manholes exist, which, nevertheless, is still the case in the great majority of dwelling-houses in the land.

Thus, through thn revelations of sanitary science, mechanical appliances have been devised like those exhibited upon the walls, by the aid of which it is now quite possible, as Dr. Corfield has proved, to put a house into such a condition of safety that we can say, with perfect certainty, that if typhoid poison is in the main sewer, it will not get into the house; and, fur-

ther, that if typhoid fever is taken into the house, when such preventive measures are taken it will *not spread.*

Sanitary science having first revealed the ready absorption by water of bad gases, as already mentioned, mechanical means have been devised by practical sanitarians to prevent the *drinking-water* in our cisterns and wells from becoming contaminated. It is common to find wells situated so near to cesspools that the water of the former is rendered impure and poisonous by the percolations from the latter. It is common to find the only supply-cisterns fixed over the closets for the convenience of having service-boxes in the same for their supply; and the trumpet overflow waste-pipe fixed in direct communication with the pan-closet or the soil-pipe.

Your exhibition teems with devices for overcoming these evils. Pan-closets are condemned, valves only are admissible; service-boxes are discarded; disconnecting waste-preventers are provided; the wastes empty into the open-air, and, as a rule, a separate cistern for drinking-water is provided.

I have suspended on the walls the illustrations of Mr. Pridgdin Teale's book, entitled "Dangers to Health," which will both amuse and instruct you; indeed, I know no better medium for opening the eyes of the popular mind to a right understanding of what to fear, and how to defend yourselves, than that very interesting volume.

Dr. De Chaumont has said that, parallel with the progress of medicine and the collateral sciences, advances have been made in sanitary science which amount to important revelations, so that it has become possible to lay down certain principles which, as we have seen, are capable of practical application to the great advantage of us all. Thus the dwelling in marshy districts has been proved, by incontrovertible evidence, to be usually followed by attacks of ague and fever of various kinds. That destitution and crowding give rise to typhus. That the withdrawal of vegetable diet produces scurvy. That smallpox, measles, and scarlet fever are communicated by contact to otherwise healthy persons. And by equally strong evidence, though not so generally accepted, acknowledged and acted upon, sanitary science reveals to us that, out of the 700,000 deaths that take place in one year in the United Kingdom, no less than one-third, or some 240,000 deaths have been traced to those particular diseases which are liable to be favored or propagated by neglected house sanitation. In fact the highest medical and sanitary authorities have decided that, by good sanitary appliances and surroundings, resulting in the maintenance of the purity of the air and water within and around our dwellings, typhoid fever, diphtheria, sore throat, and cholera might be rendered exceptional diseases, instead of being, as they now are, the fruitful causes of illness and death to the alarming extent these statistics attest.

Let us proceed to notice some further revelations of sanitary science. We have glanced at the cause and cure of defective house-drainage and water-supply, we will now refer to the *nature of the sub-soil.* As I have said elsewhere, a damp site makes a damp house, not only by the surface dampness of the surrounding ground, but, as Professor Kerr has also pointed out, by the ground air, which forces the moisture under and into the house, drawn forward by the very means adopted for warming the interior, which by lightening the weight of the internal air, makes a free passage for the heavier cold damp ground-air in the direction of the least resistance.

There are two general divisions in classifying soils—the pervious and the impervious. *Pervious* soils are those like gravel, sand, and soft limestones, which allow of the free passage of water through them, and if there is nothing to obstruct its free passage, and the level of the water in the ground is sufficiently deep, the upper surface upon which the house is built is always dry and healthy. If, however, the gravel has no deep outlet for the water which passes into it, owing to its being situated in a basin of impervious soil, so that the level of the water in the soil is brought very near the surface, then it is necessary to find an outlet for the accumulated water by artificial means, called land drainage.

Impervious soils are those chiefly composed of various clays, which do not allow the waters to sink into their depths, but only suffer it to flow over their surface, and consequently the garden soil

gets super-saturated, and if the land is level the water is longer in getting away, and the evaporation of the moisture in and upon the soil produces a humid, damp atmosphere, very injurious to health, and requiring very careful surface drainage to overcome.

The public roads, forecourts and areas of town houses are usually well drained, so that less evil comes from this source in the front of such houses, as a rule; but the back gardens are commonly neglected, and the basements suffer in proportion. It is obviously important to look to the surface and subsoil drainage of the site of the house you inhabit. But this is not all. Suburban villas are not always built on natural soils at all. The brickmaker has sometimes preceded the builder in impervious soils, and the gravel and the sand merchant in pervious soils; and to bring the land to one uniform level, the well-known notice board has appeared, inscribed "Rubbish may be shot here," which, interpreted, means, "the seeds of disease may be sown here." The foregoing revelations of sanitary science have led me to cover the basement floor of my own and of my clients' houses with a solid and practically impervious flooring. Let me give you the prescription. Provide deal, pitch pine, oak or other wood blocks, 7 in. by 3½ in. by 2 in. thick. Burnettise them, and lay them in herring-bone or other patterns, bedded in gauged lime-and-hair mortar, after first dipping each block half its depth into hot pitch, the whole resting on a solid foundation of ground lime or cement concrete, averaging 6 in. thick. The interstices of the blocks to be filled in with Portland cement powder swept over them, the surface to be then washed with water, which, setting the cement in the joints, makes a permanent floor, which may be polished, or ornamented by Mr. Webb's process exhibited in the Eastbourne Exhibition.

So far we have been considering the effect, upon the health of the community, of bad drainage and water supply, and damp subsoils. But when we have succeeded in ventilating our drains and water, and subsoils *out* of our houses instead of *into* them, we have next to consider how to *maintain the purity of the air of the rooms we inhabit and defile* with our own breathing, our house warming and lighting, and cooking, etc. In this matter also sanitary science has made many revelations of more or less gravity. The late Dr. Parkes has shown in great detail the various sources of impurity to which the air of enclosed spaces is subject, and the particular diseases to which such impurities give rise under the title of "Ventilation"—a term which he restricts "to the removal by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of the combustion of lights in ordinary dwellings; to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions of surrounding dwellings."

To expound the revelations of sanitary science by which the above impurities are detected, measured, and overcome, is my next intention; and, having regard to the mixed nature of my audience, I will do so in as popular a manner as possible.

It is usual to measure the impurity in the atmosphere by the proportion of carbonic acid it contains—not because this is the only or even the chief cause of its unhealthiness, but because the presence of carbonic acid is indicative of the proportional existence of other impurities, viz., foul organic matter and moisture, and also because the amount of carbonic acid can be accurately measured, and therefore may be usefully taken as an index of impurity generally.

The average amount of carbonic acid in the air outside of the house is four parts in 10,000 parts; when it reaches six parts in 10,000 inside, the room begins to be stuffy. Dr. De Chaumont has shown that about 3,000 cubic feet of fresh air per person per hour are necessary to preserve the air quite fresh; practically, however, no more than 750 cubic feet per person per hour is attainable in this country without producing draughts.

As Dr. Corfield observes, the air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. Thus the air that we expire con-

tains a certain quantity of foul or putrescent organic matter. It is charged with moisture, and contains about five per cent. less oxygen, and nearly five per cent. more carbonic acid, than the air we inspire. Add to this that every foot of gas consumed is equal to the addition of one person's expiration, and the need of changing the air is quite obvious. This change of air can only be effected by the admission of fresh air and the concurrent abstraction of foul air. It is not enough to provide for the extraction of air without providing for its incoming, because the effort of natural forces seeking equilibrium will cause the air to be drawn through every crevice in the doors and windows, and even through solid walls and floor, creating currents of air *en route* to the motive power; viz., the partial vacuum which the fire in the grate produces. Neither is it sufficient to provide for the admission of air if there are no means of outlet; and if the chimney-flue is closed it will not enter of itself at all, but will require to be forced into the room, by which process the occupants of the apartment will feel no more delightful sensation than is experienced by a descent in the diving-bell at the Polytecnic.

In ordinary houses, the chimney is a sufficient ventilator when associated with a means of feeding the chimney with a supply of air, to prevent its feeding itself by drawing from every crevice as aforementioned. To feed the fire directly, however, would probably prevent draughts, but it would decrease the warmth and leave the room unrefreshed by the change of fresh air for expired air. Consequently it is obviously desirable to introduce the air in such a way that it may do all the good it can before it reaches the fire and is swallowed up by the chimney current.

Now, it has been proved by experiment that the ordinary current up the flue of a sittingroom fire-place is at the rate of from three to six cubic feet per second, or 300 cubic feet per minute, or 18,000 cubic feet per hour. Consequently, allowing 1,000 cubic feet of air per hour as necessary to be extracted for each occupant of any chamber, obviously one sitting-room where the fire-place flue is a sufficient extractor for eighteen persons; if 3,000 cubic feet per hour be insisted on, as recommended by Dr. De Chaumont, then six persons are efficiently provided for by this means, which is all-sufficient for practical purposes in dwelling-houses, except in the reception-rooms on party nights, when a much larger volume of expired air will be required to be extracted, to make way for the equivalent of fresh air which it is necessary to introduce to keep up the interchange and to maintain the purity of the air generally. In winter this fresh air can be warmed in its passage.

The foregoing principles underlie the best of the mechanical appliances constructed for the ventilation of dwelling-houses. And proceeding upon these lines, Mr. Tobin has credit of reviving an old principle laid down by Mr. Whitehurst, F.R.S., and published in 1794, and of putting it into practical use most successfully at the Ophthalmic Ward of St. George's Hospital, which is a room about 20 ft. square by 14 ft. high. Mr. Tobin closed all extract ventilators except the open fireplace, which is necessary to keep going, winter and summer, and day and night, to maintain the velocity of the upward current in the chimney, which was thus retained as the only and sufficient extractor. He next provided some eight or ten semi-circular zinc shafts, about 5 in. or 6 in diameter, and 4 ft. or 5 ft. high, and fixed them at the four corners of the room, and equidistantly between them. These shafts are connected at the foot with horizontal channels leading through the thickness of the walls to the outer air, and form the fresh air inlets,—one set of shafts being in communication with the channels leading to the outer wall gratings fixed on one side of the building, and one set of shafts communicating in a similar manner to gratings on the opposite side of the building. This was an afterthought, for when all the shafts communicated with the outer walls on one side of the building only, the room was either supplied with too little or too much air, just as the direction of the wind might happen to be towards or away from the said inlet gratings. In this way the fresh air was introduced and the foul air extracted. No draught was felt by the patients, much less by myself and other professional visitors who congregated round the fire expecting such a result. In fact, the prophecy of Mr. Whitehurst,

delivered a hundred years before, was fulfilled thus: Given, an air-duct about 3 ft. or 4 ft. long, and 5 in. or 6 in. diameter, fixed in either corner of the room most remote from the fire, and communicating with the external air, the incoming air will rise in a perpendicular direction to the ceiling, and being gradually diffused will soon acquire the temperature of the room. No person will be sensible of it, and the flame of a candle will not be in the least disturbed by it.

The Sanitary Engineering and Ventilating Company have done their best to improve upon this suggestion, and at the International Medical and Sanitary Exhibitions at South Kensington, their various models were exhibited, showing how the blacks and dust may be intercepted in the passage of the outer air into the interior of the dwelling, and your own exhibition also furnishes examples.

The introduction of fresh air is specially provided for in a variety of stove-grates, and notably by Boyd's Hygiastic School Board stove; under the iron hearth, and through the gills at the back of the grate the fresh air passes, and is warmed in winter before it enters the room through the gratings in front of the stove, which are proportioned to the size of the room in which they are fixed for both warming and ventilating purposes.

Mr. Boyd does not consider the chimney a sufficient extractor, but always recommends extract ventilators to be used with his stoves, fixed at the foot of an air flue built in the upper part of the wall opposite the stove, with not only a means of opening and cleansing the same, but also of heating the extract flue by a Bunsen gas-burner, as a means of rarefying the air in the shaft, and increasing the upward draught. If the objection is made that by forming extract flues you will materially increase the cost of the building by doubling the width of the chimney breasts and stacks, I answer "No! If you are willing to do as I did, thirty years ago, at Mr. Boyd's suggestion, instead of making the withe or division between the flues of solid half-brickwork, make a hollow flue by the introduction of cast-iron flue plates the thickness of a slate, leaving a clear 4 in. by 9 in. or 14 in., as the case may be, for a ventilating flue warmed on either side by the smoke-flues between which it is situated, occupying no more space than the ordinary flue-withe, and delivering into the open air 3 ft. below the smoke-flues through louvered openings.

But sanitary science teaches us to regard ventilation as something more than this. It has revealed to us that ventilation cannot be rightly studied and practised without due consideration of the mode of heating and lighting intended to be adopted in the room to be ventilated. Indeed, the temperature of the air within a room and without it, being different in density, in proportion that either is hotter or colder than the other, is one cause of the pressure of one atmosphere against another in search of that equilibrium which nature is ever seeking, and never finding for any length of time together. The whistling wind rustling through the woods and forests bloweth where it listeth; we hear the sound of it, but cannot tell precisely whence it cometh or whither it goeth, until we have traced to its source the provocative cause of its movement, which will be found to arise from the variations in humidity, temperature, and consequent density and pressure of the heavier against the lighter and brighter atmospheres, with which the former impinges upon the latter. Thus the draughts in a room are the result of the cold air of the street or passage in its struggle to get to the warm air of the room, and particularly that part of it from which the heat is generated and projected.

When two rooms are of the same temperature, the air is stagnant; that is to say, no movement of the air from one to the other will take place by the opening of a means of communication between them. It is obvious, therefore, that if the whole of the interior of a house were equally warmed without the provision of inlets for fresh and outlets for foul air, there would be no change of air from one part of the house to another. But each room might be separately lighted, warmed and ventilated by inlets and outlets, and yet the same temperature might be maintained, but with this difference, that there would be no stagnation, but pure fresh air, warmed as it entered for free inspiration, and withdrawn as by expiration or combustion it became impure. In the ventila-

tion and warming of the house, the hall and staircase should not be forgotten. The best salvation from the wasteful consumption of fuel is the withdrawal of the cause of the draughtiness of rooms when the door is opened, arising from the difference in temperature between the sitting-room and the hall, by the introduction of a good hall fire or other system of warming the entrance hall and staircase.

With reference to the lighting of rooms, of course the softest and most agreeable method is by wax candles, but the cheapness and brilliancy of gas, and its easy application has led to its general adoption, regardless of the sanitary consequences. For as Dr. Corfield observes in his Cantor lectures, "Candles, lamps, and gas all help to render the air impure."

"It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man's respiration does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps and candles, and so it is, when the quantities of light are not compared; but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles." Common sense at once suggests that the products of combustion should be carried away, and the heat generated by the process should be utilized to expedite its removal, and several manufacturers have turned their attention to this desirable end, and at the International Medical and Sanitary Exhibition, and at your own exhibition in this town of Eastbourne, examples may be found of many means to attain this end. Strode's sun-burners, Benham's globe light, Faraday's pendants, and many more appliances, all seek to give practical application to the principles above referred to. But we are fast arriving at the best solution of this difficulty through the agency of electricity. The sanitary side of this new lighting power is to us the most interesting. By the Lane-Fox and Swan incandescent lights, unequaled brilliancy, steadiness, and continuity of light are capable of being maintained, and this all produced within a vacuum formed within the globe of glass in which the light is produced; and consequently, by the use of these lights (which are becoming more common every day and will soon supersede gas altogether), no heat is generated, no dirt is caused, and no products of combustion mingle with the air of the room, from which no provision needs to be made in its ventilation for this system of lighting, which, as hereinbefore explained, is so necessary in the case of other lights.

This brief review of the revelations of Sanitary Science would not be complete without a few words on heating.

The natural process by which the temperature of the air is raised is either by radiation or conduction. Conduction, or rather conducted heat, is the warmth given off to the air by heated surfaces brought into immediate contact therewith. Such heat in the ordinary fireplace is carried up the chimney, and the systems in use for generating it are known as hot air stoves or flues, hot water carried in cast iron pipes at low pressure, or in wrought iron pipes at high pressure, and steam pipe apparatus.

Radiated heat is like that of the sun, which passes through the air as light without heating it, into the earth or any intervening substance, from which the heat is given off gradually to the atmosphere, creating the difference between sun and shade temperature. Thus it is that the conducted heat of an open fire goes up the chimney, as I have said, and about a sixth part only is radiated into the room, passing through the air without sensibly heating it, but warming the first obstacle to its progress, such as the inclosing walls and furniture, by which the radiated heat is given off to the air of the room, raising its temperature as required. It cannot be called an economical mode of heating, being but one-sixth of the means to the end; but it is the most enjoyable and the most healthy. All the products of combustion pass up the chimney, and draw after them the impurities and denser air of the room lying lowest, while the vivifying rays of the crackling fire heat without scorching the surfaces that warm the air of the room insensibly.

The primary but not the exclusive object in the improvement of an open fire stove must obviously be the increase of

its radiating power, by reflection from heated polished surfaces in close contact with the fire, and this is done by many of the best stoves—one of the latest of which is Messrs. Comyn, Ching & Co.'s new stove called "The Paramount." In this case the fire basket or grate is quite disconnected from the brickwork surrounding it, and equally so from the metal case, excepting at the point of contact with the bracket which sustains the circular grate. Thus the fire is enabled to radiate as from a center all round. The rays of heat emitted from the back and sides of the fire basket, impinging on the metal reflector of the back and sides, are reflected forward into the room and utilized, instead of being lost as before.

The secondary object, economy in fuel, is attained by the first, and by bringing in conducted heat from chambers provided at the back of the grate; and the third is the consumption of smoke. This has occupied a great deal of attention of late, with the object of purifying the air of blacks and the reduction of London fogs. An exhibition of stoves designed with this object will take place in London in October, and we shall soon see with what result.

In the meantime, the "Wonderful Grate," exhibited by Messrs. Smith & Co., at the London Sanitary Exhibition, accomplishes a great deal in this direction. It is an open fire grate, and yet consumes its own smoke. It burns anthracite coal. It is fed with fuel in the morning, and needs no attention till night, until the fuel is consumed. It requires no stoking, yet has always a clear, bright, red fire, the radiating power of which is considerable. Then there is Dr. Siemens' grate, which is an attempt to combine gas with anthracite coal, and a host of others.

The history of the heating and ventilation of the British House of Commons, both old and new, is perhaps as instructive a lesson in this branch of sanitary science as any which could be named. Sir Christopher Wren, Captain Cook, Sir Humphrey Davy, the Marquis de Chabannes, and many others tried their hand at the old building. Dr. Reid, Mr. Gurney and the present Dr. Percy, have had their way with the new. However, it is not my intention to refer to public buildings now, but only to draw attention to the importance of the principles laid down by sanitary science which are applicable to all householders, and the revelations of which I have now traced as they have influenced house drainage and the ventilation of the same, house warming and lighting, and the ventilation of the rooms in which we live and move and have our being.

If I have made no new revelations, I have at least endeavored to popularize the old, and I think we may look forward with confidence, as the result of such exhibitions as that which you have inaugurated in this town that their need will become less and less as time advances, knowledge increases, and the evidence of the value of these revelations accumulates. It is a work of "sweetness and light." It aims to realize that which hitherto has existed more in the imagination of the poet than in fact:

"Home, *sweet* home."

A NOTE ON CURRENT DEPHOSPHORIZING PRACTICE.*

By SYDNEY GILCHRIST THOMAS and PERCY CARLYLE GILCHRIST.

From "Iron."

It being now just three years since the first detailed communication on the subject of the technical possibility of a complete and direct dephosphorization being effected in the Bessemer and Siemens processes was offered to the Institute, and nearly two years since the first working on a large scale was commenced, it has been intimated that it would be interesting to many members to know in what position the matter now stands. The more strictly scientific aspects of the question having been already treated of at various times, it is only proposed at present to give a very brief *résumé* of the technical results obtained at some of the leading dephosphorizing works, with the view of afford

*Paper read at the Autumn meeting of the Iron and Steel Institute.

ing members the necessary data for drawing their own conclusions as to the technical and economical status of the dephosphorizing process, and giving some materials for forming a judgment on the relative advantages of manufacturing iron by the fluid or ingot processes as compared with the puddling or piling process. It is to be premised, however, that, as there are at present in operation only three works in which the plant has been specially arranged to meet the requirements of the new process (none of which are as yet entirely completed), it is obvious that the average results here given are very far indeed from representing the economical practice likely to be obtained in new or specially adapted plants.

The data here given are based on the results obtained in the present current manufacture of dephosphorized steel, which amounts to between 27,000 and 29,000 tons a month. It may be added that the make for November, and probably for October, will considerably exceed 30,000 tons, or say at the rate of 360,000 tons a year; while in the course of the next few months, twelve more converters, now nearly finished, will come into operation, bringing the yearly make up to considerably over half-a-million tons. With regard to the question of production, it may be noticed:—(1) That at present, in the modified Bessemer process, the production of steel per lining is considerably less than in the old process, and that, therefore, the vessel plant, or the facilities for changing the vessel, should be increased for a given make. (2) That the make per unit of blowing and hydraulic engine power (and in consequence per unit of boiler and crane capacity) is substantially the same for both processes, and that, therefore, no increase in engine, boiler, or crane power is required for the dephosphorizing Bessemer process. As an illustration of the actual present productive capacity of old works modified for the new process, it may be mentioned that there are now at work in Germany two three-vessel basic pits, each regularly turning out twenty-four or more charges per twenty-four hours, which probably equals the full average of English practice with two-vessel hematite pits. This is the more remarkable as one at least of these pits is a very old and contracted two-vessel pit into which a third vessel has been squeezed. At another German works, with an old two-vessel basic pit, which works on day turn only, the average basic output is eleven charges in the twelve hours; while at a fourth works with an old two-vessel pit, twenty-two casts are regularly obtained per twenty-four hours.

The interest and redemption of the cost of a third vessel and its adjuncts would amount to a charge of about $1\frac{1}{2}d.$ per ton of steel produced. With the Holley system of removable shells there would seem to be no reason for anticipating any difficulty in obtaining from a single two-vessel basic pit any amount of steel that could be handled, or say at least fifty charges per double shift. In America a still larger production is expected from the new basic works. The durability of linings is intimately connected with the subject of productive capacity. In present practice the necessity for considerable repairs to the lining arises after from 35 to 90 blows. Thus it appears from the returns from various works that more or less extensive repairs are required on an average after 70, 60, 45, 40 and 60 charges respectively, or say an average of 56 charges. Practice varies much as to the mode of conducting these repairs. There are very important advantages in the system worked by Mr. Richards, of performing them with liquid lime-tar without cooling the vessel. This enables a badly-worn lining to be made as good as new in less than fifteen hours, as a maximum, after the last blow. In some works, when a vessel is badly worn the whole lining is knocked out and replaced; in most, however, the more economical mode of merely renewing the worn portion is employed, and an absolutely new lining is only put in after many months' working.

Not less important than the durability of linings is that of durability of bottoms. The average number of blows per bottom as reported by ten works is as follows: $8\frac{1}{2}$, 21, 13, 14, 18, 12, 14, 15, 12, or an average of over 14 blows. In nearly all cases only pin bottoms are used, so no tuyeres are replaced. The average would be higher if only the results of the past few weeks were taken. In many cases lime bottoms have run for

24 heats, and even over. The average duration of silica bottoms in England would appear to be under 11 blows, the best average being 14, and the lowest 9, besides replacement of tuyeres. Perhaps, however, the best criterion of the relative durability of basic lining material is afforded by the consumption of refractory basic materials for linings and bottoms per ton of steel produced. Unfortunately, reliable figures on this head are not always obtainable. The following represents the total consumption of basic refractory material (in the only works in which trustworthy account seems to be kept), in kilogrammes per 1000 kilos (1 ton) of steel: 45, about 40, 38, 70, or a mean of 48 kilos, or rather under 1 cwt. per ton of steel. The 70 kilos being in a new works not yet in regular work, it may be assumed that 48 kilos is more than the actual mean, which is probably under 45 kilos. The consumption of gannister and tuyeres in the hematite process is probably about 30 kilos. The consumption of coal in the burning and shrinking of the calcareous refractory lining and bottom material varies very greatly, being now considerably less than in early practice. Thus, for the production of a ton of prepared refractory basic material, the consumption of coal varies between 17 cwt. and 3½ tons at different works, being 2 tons, 3 tons, 3½ tons, 17 cwt., 20 cwt., and 22 cwt. At the works, where the cupola mode of preparation is adopted, the consumption of coke is 21 cwt., 18 cwt. and 15 cwt. With good firing arrangements and regular work, there seems no difficulty in obtaining a ton of lining material with a consumption of considerably less than 24 cwt. of coal, or say 16 cwt. of coke.

At the average cost of limestone and coal or coke in English steelmaking districts, the maximum average cost of basic lining material would be considerably below 27s. a ton; in some it would be below 20s. The cost has been reduced already very much below the first figure in several existing works, and in one at least below the second. Taking as an average 1 cwt. of basic material (including tar) per ton of steel made, the cost of material would be about 1s. 8d. per ton of steel produced. Should it prove practicable to commercially produce magnesia at a very low figure, this may also prove a useful material. The consumption of lime for additions varies between 13½ and 17½ per cent. on the weight of the pig used—say, an average of rather over 15 per cent. on the steel, or 3 cwt. per ton. The result of recent trials makes it probable that a little over 2 cwt. may prove sufficient. The slag produced in conversion is in all new works allowed to run direct into a slag bogey, so that there is no handling of slag at all. The composition of the slag, *i. e.*, its content of iron, manganese, lime, magnesia, and phosphorus, is such as to give it in the blast furnace—where it is used in all works having blast furnaces—rather more than the value of an equal weight of limestone.

The loss of metal, including remelting (when practiced), varies considerably, being in all cases in excess of the loss obtained in the hematite process. The absolute loss reported from eleven works is 14, 13, 16½, 16, 16, 15, 15½, 11, 13½, 17, and 19 per cent. respectively, or an average of 15 per cent. There is, however, reason to believe that the 17 and 19 per cent. losses reported are abnormal, and the latter, reported by a new work for the first few months' working, is probably incorrect. The loss from shots of metal being entangled in a somewhat cold slag is always exceptionally large at the commencement, owing to slow and therefore cold working, as well as to bad cupola working. The average loss in conversion in English hematite practice is probably about 12 per cent. The duration of the blow, including the after-blow, varies from thirteen to twenty five minutes, averaging about eighteen minutes. In one case, with 3 per cent. of phosphorus, the total blow averaged under ten minutes. This does not include sampling, which, when practiced, usually occupies three or four minutes more. The sampling period would in America be doubtless utilized in blowing the second vessel. Blast-power sufficient to finish a blow in about fifteen minutes is desirable. The average pig used in various works varies in composition as follows: White iron is generally preferred; at Eston, however, Mr. Richards blows white, grey, and mottled indifferently, all direct from the furnace. Only direct working is carried on at Eston and Creusot, and mixed

direct and cupola working at two other works.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Phosphorus	1.75	2.00	2.5	2.5	2.5	2.	2.2	3.00	2.	2.	1.0
Silicon... ..	1.2	1.0	.5	.5	—	.70	.80	.50	.70	1.3	1.00
Manganese.	.35	1.00	2.00	1.7	1.00	—	1.2	2.0	1.0	1.7	1. 6
Sulphur....	.10 to .2										

All these varieties, which are the average of the charges used at the several works, work well, but considerably wider limits of composition are actually employed.

As to the quality of steel produced, the rapid extension of its employment for every purpose for which Bessemer steel has ever been used (excepting, perhaps, the manufacture of Bessemer tool-steel) is the best evidence. That dephosphorized steel is even superior to hematite steel for certain purposes, such as boiler plates and wire, is now pretty well agreed. The total number of converters at present regularly working on phosphoric iron is thirty-six, of which, however, eight or nine are of less than four tons capacity. Thirty more converters specially designed for the process are now under construction. Several Siemens furnaces have been in regular work for some time, but details of their operations must be reserved for the present.

If no formal acknowledgment is made by name to the many able co-workers in Germany, Austria, France, Belgium, and England, who have contributed so largely to the development of practical dephosphorization, and to furnish materials for this note, it is only because acknowledgments are due to so many that it would be invidious to particularize a few. As, however, Mr. Richards is absent, it may be permissible to renew the expression of a feeling of deep indebtedness to him—a feeling in which all interested in dephosphorizing progress will certainly join.

ON A BAROMETER FOUNDED ON THE EQUIVALENCE OF HEAT AND PRESSURE ON THE VOLUME OF A GAS.

By C. DECHARME.

From "Comptes rendus de l'Académie des Sciences," Abstracts of Institution of Civil Engineers.

THE volume of a gas placed under determinate conditions can be reduced by the same quantity either by increasing the pressure or diminishing the temperature. In the same way the volume may be increased by a diminution of pressure or elevation of temperature. There must therefore be a temperature capable of producing upon a given gaseous mass the same change of volume that a given pressure will produce upon it, and *vice versa*. It is proposed to formulate and represent graphically this equivalence, in order to make it serve for the determination of the atmospheric pressure, the volume and temperature of the confined gas being known.

If V_0 represents the volume of a gas at the temperature 0 and the pressure H_0, and V the volume at the same temperature and the pressure H, thus, according to Boyle's law

$$V = V_0 \frac{H_0}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Again, according to the law of expansion of gases (the pressure remaining constant)

$$V = V_0(1 + a\,t) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

a representing the coefficient of expansion, and t the temperature.

Equating these values of V expresses the fact that pressure and heat successively applied to a gas, bring it to the same volume, *i.e.*,

$$V_0 \frac{H_0}{H} = V_0(1 + a\,t),$$

$$\text{whence } t = \frac{H_0 - H}{Ha} \quad . \quad . \quad . \quad . \quad (3)$$

Make $V_0 = 1$, the formulas (1) and (3) may be applied to the special cases of atmospheric conditions, that is to pressures varying from 710 millimeters to 790 millimeters, and to temperatures from $-25°$ C. to $+40°$ C., between which limits Boyle's law may be considered as rigorously exact, and the coefficient of expansion as constant and equal to 0.00367. Make $Ho = 1$ atmosphere = 760 millimeters, and finally, after substitution of V in 3, we obtain

$$V=\frac{760}{H} \text{ and } t=\frac{V-1}{a}=\frac{V-1}{0.00367}.$$

The instrument employed consists simply of a mercury or alcohol thermometer, and an air thermometer for measuring the volumes of the gas corresponding to the observed temperatures. The details of construction are given in the original memoir presented to the academy.

The unit volume V_0 having been experimentally determined at the normal pressure, the volumes V of the gas at various pressures H, and the equivalent temperatures are calculated by means of the preceding formulas. By this means a numerical table is obtained, which can be represented graphically by means of a curve C_0.

If the temperature remained at 0, the pressure alone affecting the volume of the gas, it would suffice to find the pressure, to read this volume on the air thermometer, and to follow on the diagram the horizontal which bears the number of the observed volume; the point of junction of this horizontal with the curve C_0 belongs to the vertical corresponding to the desired pressure.

But the temperature being generally other than 0, the volumes V′ corresponding to the various pressures are obtained by means of the formula $V'=V(1+at')$; if $t'=10$ for instance $V'=V\times 1.0367$, or in other words each value of V of the first table must be multiplied by 1.0367. The temperatures equivalent to the pressures will be calculated by the formulas $t=\frac{V'-1}{a}$. In this way a curve C_1o will be obtained, and other curves in an analogous manner.

To find the pressure, the actual temperature on the ordinary thermometer, and the volume on the air thermometer are observed.

Then taking the diagram, the curve corresponding to the observed temperature is followed until the horizontal line of volumes is reached, the pressure is found on the equivalent vertical line. Thus if $t=10°$, $V=1.06$, H will be found to be 743.7 millimeters. For intermediate temperatures, the position of the corresponding lines is easily observed, and the pressure to within one-tenth of a millimeter.

This instrument may be called absolute, as it gives the real pressure without further correction, and if the curves are traced for every 2° on a convenient scale, it becomes an instrument of great precision.

REPORTS OF ENGINEERING SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The last number of the "Transactions" contains the following papers:

No. 227. Repairs of Masonry. by O. Chanute.

No. 228. Strength and Ductility of the Copper-tin-zinc Alloys. By Robert H. Thurston.

ENGINEERS' CLUB OF PHILADELPHIA.—The first meeting of the season was held on October 15th, 1881.

The Secretary exhibited, on behalf of Mr. J. Milton Titlow, screws which had, for 6¾ years, held together three 2-inch courses of yellow pine planks in the floor of Fairmount Bridge, Philadelphia, which planks had been treated in some manner with creosote. The screws in question are much corroded, the original diameter being diminished about ¼ at the middle of the screw, where the fiber of the iron is distinctly exposed. It seemed, however, to be the universal opinion of the members present, that the corrosion was due entirely to the presence of water between the planks, and not at all to the creosote oil, which would preserve rather than destroy the iron.

The Secretary exhibited copies of a drawing which had been made by a method giving more economical and better results in many instances than the ordinary blue process. Mr. Frederic Graff stated, in this connection, that the ordinary letter-press was the invention of Watt, and that the original was still in existence.

The Secretary read a detailed description of the moving of the Hotel Pelham, at Tremont and Boylston streets, Boston, for the purpose of widening Tremont street. This hotel is built of freestone and brick, 96 and 69 feet frontage. The Boylston street wall is supported on 8 granite columns 12 ft. high, 3 and 4 ft. square. There is a basement and seven stories above the sidewalk. Height above tramways on which it was moved, 96 ft. Weight, 5,000 tons, exclusive of furniture, which was not disturbed during removal, as also were not the occupants of the stores on first floor and some of the rooms, the various pipe connections being kept up with flexible tubes. Careful experiments with models showed that if the lower part of the building was firmly braced, there was no danger of shifting in the parts above. The general arrangements consisted of heavy and substantial stone and brick foundations for iron rails and rollers, and the building was forced to its new position by 56 screws, 2 inches diameter, ½ in. pitch operated by hand against timbers arranged to uniformly distribute the pressure against the

building. Much care and ingenuity was displayed in the details of the arrangements and work. Two months and twenty days were occupied in preparation. The moving itself was begun on August 21st, and finished on August 25th, but the actual time in moving was but 13 hours and 40 minutes. The greatest speed was 2 inches in 4 minutes. The hotel moved about ⅛ inch at each quarter turn of the screws. The whole distance moved was 13 ft. 10 inches. 4,351 days labor was required for the work. The whole cost was about $30,000. This is the largest building that has ever been removed, although larger have been raised, which latter is a much simpler and less risky operation. The complete success of this undertaking is shown by the fact that cracks, which existed in the walls prior to removal, were not changed by the operation. Paper was pasted over them before commencing, that any change might be seen.

President Strickland Kneass exhibited a drawing which had been sent to him by telegraph during his recent visit in Europe.

Prof. L. M. Haupt exhibited a note book, loaned by Mr. John C. Trautwine, containing many complete and beautiful sketches of bridge construction, notably of the celebrated Wernwag Bridge, which crossed the Schuylkill at Callowhill street.

AMERICAN SOCIETY OF MECHANICAL ENGINEERING.—The annual meeting of the American Society of Mechanical Engineers was held, Nov. 3, in this city.

The programme consisted of an afternoon and evening session on Thursday, and a morning and afternoon session on Friday. The papers read were as follows: "A Mill Floor and its Supports," by C. J. H. Woodbury; "Fire Protection of Mills," by the same gentleman; "A Self-Packing Valve," by H. F. J. Porter; "Standard Weights and Measures," by Mr Partridge; "A New Method of Keeping Drawings," by Charles T. Porter; "Observations on Railway Structures from Ohio State Railway Service," by Prof. S. W. Robinson.

ENGINEERING NOTES.

THE PROPOSED NEW TAY VIADUCT.—The plans of the proposed new Tay bridge, prepared by Mr. W. H. Barlow, C.E., are now being exhibited at the North British Railway offices, Edinburgh, for inspection by intending contractors. The new bridge, which is to be built on the girder principle, will commence on the south side, about 16 feet west of the former bridge. At this end four brick arches are shown next the shore, each having a span of 50 feet. The girder work then commences with a span of 118 feet from center to center of the piers, and is continued with ten spans of 129 feet, and thirteen of 145 feet from center to center of the piers, until navigable portions of the channel are reached. Here there are thirteen wider spans, eleven being each 245 feet, and two 227 feet each. Of these spans the first four are carried to the greatest height of the structure, and give 77 feet of clear headway above high-water mark. From this point the line of the bridge commences to fall towards the north or Dundee side, at a gradient of 1 in 114, there being one span of 162 feet, ten of 129 feet 6 inches, and one of 127 feet 6 inches. These spans carry the bridge on to the commencement of the curve towards Dundee; and twenty-five more, each of 71 feet, take the structure to the side of the proposed extension of the esplanade. Several other spans take the bridge on to the point where it is run into the level of the existing arches. The bridge is to be constructed for a double line of rails throughout. The foundations in the river bed will be formed of two wrought-iron cylinders, placed at a distance of 26 feet apart from center to center, and filled with concrete. These cylinders rise to the height of within 2 feet of low water mark, where brick will be used, filled in also with concrete. This brickwork is to the height of 8 feet above high-water mark, at which level the cylinders are connected, and made to form a solid foundation, topped with a course of ashlar. Rising from this foundation, two piers are formed of wrought-iron pillars braced together, and encased with iron plates of from three-eighths to seven-sixteenths of an inch in thickness. The piers, thus constructed, are connected with each other near the top, and the whole has the appearance of a high and strong-built arch on which to place the girders. The principal piers are octagonal in shape, with a diameter varying from 11 feet to 14 feet 6 inches. The spans are each composed of four girders, with the exception of the higher spans. These are of two girders connected together, top and bottom, with bracing and flooring. The bridge throughout its whole length will have a parapet of between 5 feet and 6 feet in height, forming a wind guard. The depth of each girder on the piers is 16 feet 6 inches. The middle girders are 28 feet 9 inches in the center and at the ends 20 feet 3 inches. They are of hog-back lattice form. The other girders are of plain lattice work, and are all connected by cross bracing, on the top of which the train travels as it did on the old bridge. At the high girders the train travels between them. The platform of the bridge is of wrought iron throughout. In the construction of the new bridge, the old one will be sufficiently near for anchorage and cranes.

THE CHANNEL TUNNEL.—The work of removing the machinery from the Abbott's Cliff heading to the shaft at Shakespeare's Cliff, in connection with the Channel tunnel experiments, is now complete, having occupied upwards of two months, and boring operations will probably be commenced again next week. The scheme is now in the hands of the South-Eastern Railway Company, who, we understand, have entered into a contract for the drilling to be extended another mile. For the present the boring will be continued in the direction of Dover. Several workships and sheds, have been erected at the mouth of the shaft and a powerful engine has been fitted up. The arrangements are now much more complete than formerly, and are calculated greatly to

facilitate the progress of the work. The cuttings from the face of the chalk are carried to the rear of the engine by cups, and afterwards conveyed in an iron skiff from the engine to the mouth of the shaft by means of pulleys attached to a drum, which is worked by machinery. With the present arrangement, the same amount of work will be able to be performed with a considerable reduction of labor, about thirty men only being required instead of double that number, as at the Abbott's Cliff heading.

A RECENT report by Signor Frescot, one of the engineers of the railways of Upper Italy, gives some interesting facts with regard to ventilation in the Mont Cenis Tunnel. The Mont Cenis Tunnel is 12,500 meters in length, and has a capacity of 500,000 cubic meters. The mean temperature is 25° C. In winter this causes sufficient natural ventilation, aided by the difference of altitude of the two extremities —132.5 meters. But in summer the external and internal temperatures are often equal, and artificial means of ventilation have to be adopted. The passage of twelve trains per day, the *Times* says, may be assumed containing 2500 passengers, each passage through occupying half an hour. The locomotives burn anthracite, which produces less carbonic oxide than coke, and the combustion is rendered as complete as possible. Now it is estimated that the average total production of carbonic acid in the tunnel per day is 6987 cubic meters, of which 6930 cubic meters are attributed to the trains, the rest to servants, passengers and lights. The normal proportion of carbonic acid in the atmosphere varies from 0.003 to 0.005. People can live in an atmosphere containing as much as 0.005. It has been proposed to attain in the Mont Cenis the same degree of purity as in our Metropolitan Railway, or 0.0015 of carbonic acid. With this view, a large centrifugal ventilator has been set up on the Bardoneche side; it is driven by water, which is abundant there. The entrance of the tunnel is closed by a door, which the trains open on passing under the arch, and close after passing. In winter, and also during some fresh nights in summer, the machine can be stopped, and any necessary repairs made. In addition to the ventilator, there is in use the compressing and aspirating apparatus that was employed in making the tunnel. Notwithstanding these means and care bestowed on the fires of the locomotives, there is reason to fear that the present ventilation would prove insufficient in case of even a small increase of the traffic.

RAILWAY NOTES.

THE following accidents occurred upon the premises of the railway companies of the United Kingdom during the first six months of this year, in which the movement of vehicles used exclusively upon railways was not concerned, namely: 51 passengers injured whilst ascending or descending steps at stations; 18 injured by being struck by barrows, falling over packages, &c., on station platforms; 17 injured by falling off platforms; and 36 injured from other causes. Of servants of companies or contractors, 3 were killed and 469 injured whilst loading or unloading, or shunting wagons; 156 were injured whilst moving or carrying goods in warehouses, &c.; 1 was killed and 126 were injured by the falling of wagon doors, lamps, bales of goods, &c.; 241 were injured by falling off, or when getting on or off, stationary engines or vehicles; 10 were killed and 125 injured by falling off platforms, ladders, scaffolds, &c.; 1 was killed and 126 injured by stumbling whilst walking on the line or platforms; 62 were injured whilst attending to stationary engines in sheds; 20 were injured by being trampled on or kicked by horses; 3 were killed and 280 injured whilst working on the line or in sidings; and 106 were injured from various other causes. 2 persons who were transacting business on the companies premises were also killed and 51 were injured; making a total in this class of accidents of 21 persons killed and 1951 injured. The total number of personal accidents reported to the Board of Trade by the several railway companies during the six months amount to 518 persons killed, and 3960 injured.

ELECTRIC RAILWAYS.—The electric railway, we hear from Berlin, is there proving to be so great a success, that it is already in contemplation to apply the same mode of moving trains to the St. Gothard Tunnel and to the Metropolitan Railway.

With regard to the St. Gothard Tunnel, it may be presumed that the coast is tolerably clear, and that if it can be shown that electric propulsion is, all things considered, likely to prove the best and cheapest, Messrs. Siemens, on the one hand, and the directors on the other, will thrash the matter thoroughly out.

With regard to the Metropolitan Railway, the case is different. There all the arrangements are made, and are in excellent working order. More than £400,000 have been expended on working stock. Not an interval of five minutes during eighteen hours out of the twenty-four passes without a train running over the rails. Before, then, any question can be raised as to change in system here, two things are requisite. First, the electric system must be shown to be as reliable and as manageable as the locomotive system; secondly, it must be shown to be considerably cheaper.

We are not advancing this statement with the view of throwing cold water on an invention which, if fully successful, will be a success of a very high order. We are only desiring to direct into the groove of practical inquiry that energy that may otherwise be wasted in vague and profitless speculation.

As to the first point, the practical working of the line, we have nothing at the present time to say. Details will, no doubt, be forthcoming, and if they prove satisfactory, experiments will in due course follow, made on some branch line or short portion of railway, where positive results can be obtained without interfering with actual traffic. We mean, of course, in this country.

What we wish to discuss is the limit of pos-

sible advantage, or the reverse, in a pecuniary sense, to be derived from the subsittution of the electric-motor power for the heavy locomotives which now propel the trains of the various subterranean railways through the metropolis.

On this highly-important subject we should be able to speak with more precision if the official returns of the English railways furnished the details of work actually done in the conveyance of traffic, whic are necessary in order to inform the shareholders of what part of their business does, and what does not pay. But notwithstanding the persistent refusal of this information, we are able, by working from the details given by the directors of foreign and colonial lines, at all events to lay down certain limits within a trifle of exactitude.

The average cost of moving 100 tons of loaded train for one mile on the railways of the United Kingdom in 1879 we estimate at 20.76 pence, out of which 5d. was the cost of locomotive power alone. From the data furnished by the Blackwall Railway we arrive at the conclusion that out of this 5d. per 100 tons taken one mile, 4d. was expended in moving the locomotive and a penny in moving the train. This 4d. per 100 tons per mile, or approximately per train mile, is therefore the limit within which any possible saving must be confined.

On the Metropolitan lines, however, the cost of locomotive power is greatly increased by the frequent stoppages, the high speed which it is necessary to get up between the stations, and the tearing action of the brakes, alike on the engines, the trains and the rails. We think it will be found that it would not cost more for locomotive power and maintenance to run a metropolitan train for twenty four miles straight on end without stopping, than to run the usual stopping train from Moorgate street to Praed-street. Thus while, owing to the good loading and the consequent low tare, the Metropolitan lines are worked at a lower percentage on their receipts than any other in the country, they cost more per mile per 100 tons than any other. The great weight of the engines, which is a necessary consequence of the high speed and numerous stoppages on the Metropolitan lines, is such as to bear a far higher proportion to the weight of the carriages than would be otherwise needful. An estimate which we made on the best data accessible in 1875, gives a cost of 45.7 pence per 100 tons per mile, or about 2¼ times the average of the English lines. For locomotive power, maintenance and repairs alone, the cost was 17.9 pence against 11d. on the average of the United Kingdom.

For maintenance and repairs, on the average of the United Kingdom, as aforesaid, the cost is 6 6d. per 100 ton miles of load conveyed. This is only 1.2d per unit more than we arrived at for the Metropolitan line. We thus have a cost of 11.3d. for locomotive power and excess of charge of repairs, on which saving would be effected if it became possible to substitute the cheapest mode of applying power hitherto indicated for the locomotive. And if we take the resistance cost (or lowest ascertained cost) at 1d., there is a margin of 10.3. per 100 ton miles out of which saving is conceivable. If we roughly allow the Metropolitan and Metropolitan District trains to average 100 tons each, load and all, a saving of 10d. per train mile would amount to more than £70,000 per annum, or to an addition of 14½ per cent. on the net profits of the two lines.

By the test of reduction to £. s. d , therefore, the conceivable saving to be effected by the replacement of the locomotive by electric propulsion is one of a magnitude well worth the attention of mechanical men, as well as of the engineers and managers of railways. Attention, of course, will be first given to those lines in which it is desirable to escape from the nuisance caused by the products of combustion. Through a long tunnel, if the passage of the locomotive could be avoided by any means that did not either reduce the certitude or increase the cost of the transit, a considerable advantage would be assured. As to the Metropolitan lines, the special cost of the sudden starting, high speed and sudden stopping of the trains is such that the advantage of doing without a locomotive would be considerably more than on ordinary railways. There is this to be urged in favor of experiment with a view to decide these points that we have named as open, that just where the advantages of superseding the locomotives would be the greatest, the margin of possible saving would also be the greatest. That so much, or that any, saving is yet shown to be possible we do not say, for we do not know. But there is a great presumption in favor of prompt and exhaustive inquiry.—*Builder.*

IRON AND STEEL NOTES.

ON THE APPLICATION OF SOLID STEEL TO SMALL ARMS, PROJECTILES, AND ORDNANCE MANUFACTURE—This paper, read before the Iron and Steel Institute, was intended to give the results obtained with cast steel containing silicide of manganese. The steel with silicide of manganese, besides the security which it presents in its homogeneity, preserves, when it has been hammered or rolled, an increased limit of elasticity, with a strong tearing strain and a good elongation. It is not necessary to seek for anything more in the manufacture of the barrels of guns. M. Nobel, who worked quite recently at the manufactory of arms at Ijef, near to Perm, has used steel with the silicide of manganese, made according to the process of Terrenoire, in the manufacture of the barrels of guns for the Russian army. The steel without blowholes in small ingots is drawn under the hammer alone. It then possesses the following mean composition :

Carbon	0.120
Silicum	0 234
Manganese	0.527
Sulphur	0.020
Phosphorus	0.109

This analysis answers to the best tests, and presented the following resistance to trials :

Diameter of the test 18 *mm.* = 0.7*in.*

	Kilos.	Lbs.
Limit of elasticity	30.13	= 66
Tearing strain	65.50	=143
Elongation per cent. measure upon 200 mm	18.7	
Contraction per cent.	48.30	
Tearing strain according to the section contracted	128.30	=282

It was claimed that the tests given proved that the steel of Bofors, applied to the barrels of guns, shows itself superior not only to that of Swedish, Bessemer, or Siemens-Martin manufacture, which has been subjected to experiments, but especially to that manufactured at Witten, of which the quality is as good. Not a rupture has taken place in it, notwithstanding the excessive charges. Before quitting the works of Bofors, the author mentioned the tests of artillery cast in steel. The Bofors Company has commenced to cast a field gun of 9 cm. bore. This cannon, which resisted the severest tests, is the admiration of artillerymen. The Swedish artillerymen wished to undertake at Bofors the manufacture of steel tube castings for cannon of 12 cm. steel hoops. The commencement of this manufacture was beset with difficulties, and success only began when they gave to the iron mould or shell a thickness of 150 mm. at least. The first four tubes, cast with a shell of only 25 mm. thick, showed numerous cracks, which made them useless. To avoid this it was only necessary that the mould in which the casting was made should be red hot ; it appears that the rapidity of cooling plays an important part in the physical structure of the metal. In fact, it is not enough that it should be without blow-holes ; it is also necessary that in the cooling no cracks should be produced. Dealing with the application of metal without blow-holes to the manufacture of armor-plates, and of projectiles to pierce them, the author said that the first question is still under consideration. It cannot be said that it is completely solved, yet a great deal has been done, and in France they are now able to obtain cast plates with nearly as much power of resistance as forged steel plates, at a price considerably less. The mixed plate of iron and steel welded together has presented a resistance so superior that the question ought to be studied anew, and they are now proceeding with some trials of mixed plates of iron and steel without blow-holes welded together. As to projectiles of cast steel—shells or solid shot—he announced some very decisive results. France and Russia now employ no other material for their naval artillery. These two Governments, starting on the principle that in war the straight target will be the exception, and the oblique target the rule, use for their projectiles of penetration the material which gives the best resistance to the oblique target—cast steel without blow-holes obtained by the silicide of manganese.

ORDNANCE AND NAVAL.

Deck Armor for Ships.—On September 13 a series of experiments was conducted at Eastney, near Portsmouth, with the object of determining the best kind of plating for the deck armor of ships of war. According to the *Times* correspondent, a great mystery was made of the occasion, and Colonel Mawbey, of the Royal Marine Artillery, who, in the absence of General Prince Edward of Saxe-Weimar, is in command of the garrison, was furnished from the Admiralty with stringent instructions as to who were to be permitted to be present at the firing. Among those who were admitted to the range were Mr. Barnaby, Director of Naval Construction, Rear-Admiral Herbert, Director of Naval Ordnance, Mr. White, Assistant Constructor of the Admiralty, Captain Codrington, Commander Beaumont, and Lieutenant Nichols of the "Excellent" gunnery ship, Mr. Nordenfeldt, and representatives of the manufacturers of the armor plates generally. Two naval attachés were granted permission to attend—namely, Captain Racchia, on the part of Italy, and Baron Barnchoff, on the part of Sweden. Similar plates to those fired on the 13th, both as regards thickness and manufacture, were some time ago subjected to the ordeal of angular fire at Whale Island, but in this case the attacking guns were Hotchkiss and Nordenfeldt machine guns, which, however formidable they may be against unarmored ships and torpedo craft, would be perfectly harmless against deck armor in position. For the first time in the history of naval construction, this armor was submitted to the roughly practicable assault of armor-piercing guns at practicable angles of inclination and elevation; and yet it is not too much to say that, with the exception of the large class of ships, which are either completely protected or are belted with ponderous side-armor, the efficiency of our latest ironclads depends almost entirely upon the integrity of the deck armor, for not only are the vital parts of the ship defended against vertical fire by an armored deck, but reserved buoyancy of the unarmored ends and the stiffness of the ram are secured by the same means in the ships of the "Comus" class, a largely increasing fleet. There is an under-water steel deck wrought over the engines, boilers, and magazine, dipping forward to the center of the spur, and with a raft body above, and Mr. Barnaby does not hesitate to say that, in virtue of its position as against blows of projectiles, this deck is as effective a protection for these parts of the ship as would be given by side armor. Even such armorclads as the "Inflexible," "Ajax," "Colossus," and "Nelson," which, so far as regards their defence against shell, are submitted as the permanent type of the ships of the future, have their armored division associated with protected ends. In the "Italia" and "Lepanto" the Italians have been even adventurous enough to dispense with side armor altogether, and to make them wholly dependent upon deck armor for their stability in action. The English Navy possesses no example of this type of vessel, but when it is considered that the "Polyphemus" and our most modern citadel ships will in ultimate circumstances be kept afloat by means of the reserve buoyancy secured by their steel decks, the importance of ascertaining practically the behavior of this protection under fire will

readily be understood. There were seven targets fired at, consisting of an ordinary iron plate, two of Sir Joseph Whitworth's compressed armor plates formed of hard steel scales, 14 inches square, and mechanically attached to mild steel backing, a plate of mild Landore steel, compressed plate manufactured by the Bolton Steel Company and by Sir John Brown and Co., and a steel-faced armor plate manufactured by Cammell and Co. upon Wilson's system. With the exception of one of Sir Joseph Whitworth's plates, which was 1¾ inches thick, each of the plates was 2 inches in thickness, and measured 12 feet by 4 feet. The targets were built to roughly represent the deck of a man-of-war. The bottom edge rested on the ground, and the plates were placed with an upward slope of 15°, being 5° for the roll of the ship, 5° for the plunge of the projectile, and 5° for the inclination of the deck. Each plate was bolted to an inch iron plate, representing the deck of a ship, the whole being supported by iron bulge beams and shored up by massive wooden balks. The range of fire was 100 yards, while the attacking guns consisted of the 18-ton 10 inch gun, firing a 404 lb. projectile with a battering charge of 70 lbs., and the 12 ton 9-inch gun, firing a shot of 255 lbs, with a 55 lb charge. To assail 2-inch plates with such weapons seemed on the face of it not unlike threatening a fly upon the wheel, or uplifting a Nasmyth hammer to crack a nut. And so it proved in the result. It was, it is believed, originally intended that the ordinary iron plate should be made to serve the purpose of a unit of comparison as to the different degrees of resistance displayed by the various plates. The guns were to be first fired with slow velocities, and when the amount of energy just sufficient to penetrate the iron target had been practically ascertained, the other targets were to be brought under fire. In the experiments of the 13th this very necessary preliminary seems to have been omitted or lost sight of, with the upshot that in the end it was found that no comparisons were possible from the fact that the whole of the plates were destroyed by the superfluous power of the attacking force. With conspicuous impartiality, the whole of the plates were served precisely alike. The firing began with full charges from each gun, and ended in the same way, the result showing that the artillery proved too strong for the plates at the given range and angle, and that the latter, whether constructed of iron or steel, or iron and steel, would in action have been unable to protect the crews of our ships from a mitraille of bolts and miscellaneous debris. It was noticed, however, that in every round (and a round from each gun was delivered against each plate), the projectile was broken up on impact, deflected from its course, and scattered in the sea, and that in no instance was the target, though smashed, penetrated by the shot. The point having failed to bite the plate, the projectile seems to have turned over and holed the plate by a blow from its base. In only one case did the shot go through the plate.

BOOK NOTICES.

Publications Received.

Graphics of Rectangular Bridge Trusses: A new method. By Theo. Kandeler.

From the Institution of Civil Engineers, through the Secretary, Mr. James Forrest:

The Prevention of Waste of Water. By Thomas Stewart.

Explosions of Firedamp. By Prof. Haton de la Goupilliere.

Abstracts from Foreign Transactions and Periodicals. Vol. 66, Pt. 4.

The Education of Civil and Mechanical Engineers. By Henry Dyer, C.E., M.A.

Contributions to the Theory of Military Mining. Part II. By H. Hofer. Translated by Capt. Charles W. Raymond.

Portland Cement for Users. By Henry Faija, C.E. London: Crosby Lockwood and Co. Price $1.40.

This is essentially a guide to the buyer and user of Portland cement, and affords detailed advice regarding the points to be considered in making selections.

The contents of the book relate to the various qualities and tests in the following order:

Weight, Fineness, Gauging, Setting, Tensile Strength, Sand Test, Chemistry, General Remarks, Application of Cement.

The appendices, containing tables and descriptions of machines, occupy about as much space as the treatise itself.

The Kinematics of Machinery. By Prof. Alex. B.W. Kennedy, C.E. With an introduction by Prof. R. H. Thurston, A.M., C.E. (Science Series No. 54.) Price 50 cents.

Treatises upon the principles of mechanism are not common, and the few really standard works are too voluminous to encourage the novice who seeks first a knowledge of leading principles only.

This little book is reprinted from Prof. Kennedy's lectures, delivered at South Kensington. The lectures were prepared for students, and to explain the advanced methods of Reuleaux. They were first republished in this country in Van Nostrand's Magazine, at the suggestion of Professor Thurston, who explains in the introduction the reasons for placing a high estimate upon this little treatise.

Dr. Carl Sachs' Unversuchengen am Zitteraal, Gymnotus Electricus, Leipzig: Von Veit & Co. Price $9 60.

This record of electrical researches will prove of interest to the physiologist rather than to the practical physicist.

Results of an economic value from electrical

eels are no more to be expected than practical illumination from fire flies, but the experiments of those scientists who have labored to fathom the philosophy of the interesting phenomena, will be regarded with deep interest by many who have neither the inclination nor the skill to attempt similar researches.

The record fills a royal octavo volume of 440 pages, and is well illustrated.

PHYSICALISCHE DEMONSTRATIONEN. By Dr. Adolph F. Weinhold, Leipzig: Quandt & Händel. Price $8.10.

Dr. Weinhold is known in this country through his valuable work on "Physical Experiments." The present work will prove equally useful to the teacher of physics. The ground covered by the treatise is not essentially different from that of the previous work.

The illustrations are numerous (483 cuts and 4 plates) and are good.

MISCELLANEOUS.

THE report to the British Association of the committee on underground temperature, read by Professor Everitt at York, showed that during the past year observations were made at three places—at the East Manchester Coalfield, the Talargoch Lead Mine in Flintshire, and the Radstock Collieries, in the neighborhood of Bath. The Manchester observations were made in three pits of great depth, and the results were as follows: Depth, 2790ft., temperature 85.3 deg.; depth 1020ft., temperature, 62 deg.; depth, 1050ft, temperature, 62½ deg. Assuming the surface temperature to be 49 deg., the increases were 29.3 deg. in 2790ft., or 1 deg. in 76.9ft., 13 in 1020ft., or 1 deg. in 78.5ft., and 13½ deg. in 1050ft., or 1 deg. in 79ft. In Flintshire, with a surface temperature of 48 deg., an increase of 14 deg. was shown at 660 ft., or 1 deg. in 47 feet; while three pit observations made in the neighborhood of Bath brought out the following results: At a depth of 560ft. an increase of 11.7 deg., or 1 deg. in 48ft.; 810ft., 13 deg., or 1 deg. in 62ft.; and 1000ft., 13 deg. or 1 deg. in 77ft. Thus it would appear that the rise in temperature is more rapid in the older and harder rocks.

M. DE PEZZER has constructed a modification of the secondary battery of M. Planté, in which he has endeavored to obtain a maximum charge with a minimum quantity of lead. He uses for the negative electrode a very thin lead plate of about ½mm. thick, the positive plate being no more than ⅔mm. thick, projecting portions of the plates which serve for connections, are, however, somewhat thicker. Besides this, M de Pezzer took two identical couples, each formed of two plates of lead of the same thickness, one of which, however, had twice the surface of the other. He then charged the couples by the same means, but arranged them so that in one case the plate with the larger surface should be the positive element, and in the other, the negative. By this means he discovered, by repeated experiments, that the couple in which the plate with the large surface was the negative electrode accumulated more electricity than the other couple. In four consecutive experiments the discharge of the couple with the large surfaced negative plate lasted at least an hour, whilst that of the couple in which the positive plate had the larger surface lasted but half an hour. Finally a couple formed of two plates equal in size to the two large ones of the above-mentioned couples gave an inferior result to that of the couple with the large negative plate. With these results to guide him, M. de Pezzer modifies the construction of the secondary battery as follows: Preserving the sizes of the plates given above, he makes the surface of the positive half that of the negative plate, at the same time making a certain number of incisions in the former. The arrangement of the plates is the same as ordinary; but, according to M. de Pezzer, his modification is capable of storing up the same quantity of electricity as a much heavier battery constructed in the usual way. The *Electrician*, quoting a French contemporary, says that M. de Pezzer promises exact figures on this point soon. M. Ducretet writes that he has obtained good results by using electrodes made of sheets of lead, having their surfaces covered with deep indentations, produced by a roller with indented surface. M. Ducretet says that these batteries form more quickly, have more energy, and are not so heavy as the ordinary ones.

THE American Consular Agent at Maracaibo describes a remarkable deposit of petroleum as existing between the Rio Tara and Zulia. Near the former there rises a sandbank about thirty-five yards in extent, and some ten yards in height. On its surface is visible a collection of cylindrical holes of different diameters, through which streams of petroleum, mixed with boiling water, gush out with great violence, accompanied with a noise as though two or three steamers were blowing off steam. Dr. M'Gregor states that from one of these holes, notwithstanding the difficulties of the position, he filled in 42 seconds a vessel containing 15 bottles, or as fast as four gallons per minute, or 240 gallons per hour, or 5,760 gallons during the 24 hours. A curious phenomenon, the *Times* says, has been occasionally seen in Venezuela ever since the conquest, consisting of a frequent lightning, which is observable from the bar at the entrance of the Lake of Maracaibo, close to the Island of Pajoseco, and which Colonel Codazzi, in his geography, attributes to the vapor ascending from the Cienega de Agua Caliente. This appearance, called by mariners "El farol de Maracaibo," is more probably due to the inflammable gas known by the natives as "El Inferno." It is possible that the supply of petroleum is abundant here and in the Republic of Columbia, where, between Escuque and Bettujoque, the laborers gather it up in handkerchiefs, which, when saturated, are squeezed out into barrels.